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April 8, 2014

Nancy K. Stoner
Acting Assistant Administrator
Office of Water
U.S. Environmental Protection Agency
William Jefferson Clinton Building
1200 Pennsylvania Avenue Northwest
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Washington, D.C. 20460

Re: Comments of the American Petroleum Institute in Response to: (1) the Center for Biological Diversity's October 18, 2012 Petition for Revised State Water Quality Standards for Marine pH; and, (2) CBD's April 17, 2013 Petition for Additional Water Quality Criteria and Guidance Under Section 304 of the Clean Water Act.

Dear Assistant Administrator Stoner:

This letter provides the public comments of the American Petroleum Institute ("API") on the following two Center for Biological Diversity ("CBD") petitions calling on the U.S. Environmental Protection Agency ("EPA") to address ocean acidification ("OA") under the Clean Water Act ("CWA"):

- October 18, 2012 Petition for Revised State Water Quality Standards for Marine pH Under the Clean Water Act, 33 U.S.C. §1313(c)(4) (the "2012 Petition"); and
- April 17, 2013 Petition for Additional Water Quality Criteria and Guidance under Section 304 of the Clean Water Act, 33 U.S.C. §1314, to Address Ocean Acidification (the "2013 Petition").

API is a national trade association representing over 540 member companies involved in all aspects of the oil and natural gas industry. API's members include producers, refiners, suppliers, pipeline operators, and marine transporters, as well as service and supply companies that support all segments of the industry. API and its members are dedicated to meeting environmental requirements, while economically developing and supplying energy resources for consumers. API's members have a substantial interest in federal agency activity pertaining to CWA §303(d) program regulations, as these regulations affect our members' discharges to surface waters and can have a direct and consequential impact on API members' ability to supply energy resources efficiently and cost-effectively.

Should EPA grant CBD's petitions, and depending on whether or how total maximum daily loadings ("TMDLs") might be implemented, API member facilities such as refineries, product pipelines, and product storage and distribution terminals, may be required to control effluent pH

and possibly other constituents through costly wastewater processing and the use of neutralizing chemicals, and yet resulting in no impact at all on ocean acidification.

Summary of Detailed Comments

API's detailed comments are attached to this letter, and a summary of those comments follows below.

- CBD identifies increased atmospheric CO₂ as the primary cause of ocean acidification, and although implementation of air emission limits is beyond the statutory bounds of the CWA, CBD's petitions may improperly result in CO₂ emission controls. Such regulation of CO₂ emissions is beyond EPA's statutory authority under the CWA.
- Contrary to CBD's claim in the petitions, ocean acidification cannot be addressed by EPA and the coastal states alone through the exercise of their regulatory authority under Sections 303 and 304 of the CWA. Because ocean acidification is global in nature, even the most aggressive domestic regulatory responses will not measurably address it. The CWA, by Congressional design, provides effective mechanisms to address localized impairment through localized controls. It cannot and was never intended to address impairment resulting from global CO₂ emissions.
- EPA's potential regulatory responses are confounded by profound data deficiencies, monitoring, control strategy, and technology limitations. EPA and the National Research Council have both clearly acknowledged these deficiencies; in its November 15, 2010 memorandum¹ to the EPA Regions, EPA found, "The [NRC] report states that a national comprehensive monitoring and assessment network does not exist to establish baselines for OA parameters (including marine pH) needed to adequately evaluate OA effects...The report also states that chemical parameters and methods for OA are well-established, but not for biological effects...other chemical parameters [need to] be monitored along with marine pH to more accurately reflect OA impacts." EPA concluded, "EPA recognizes that information is absent or limited for OA parameters and impacts at this point in time," and, "...the majority of the States do not have detailed monitoring protocols, assessment methods, or the high-resolution equipment needed to measure and implement the marine pH criteria." API is not aware of any regulatory or state monitoring program developments since this memorandum was written that would alter these conclusions.
- Taking into account existing knowledge about ocean acidification and its effects, EPA has already addressed the sufficiency of existing state marine pH criteria. EPA's November 15, 2010 memorandum, issued in direct response to CBD's legal challenge of the State of Washington's 303(d) impaired waters list for not including a coastal marine pH impairment, concluded, "Currently all 23 coastal States and five Territories...have marine pH water quality criteria...in place that are similar to EPA's CWA 304(a)(1)

¹ "Integrated Reporting and Listing Decisions Related to Ocean Acidification," Denise Keehner, November 15, 2010).

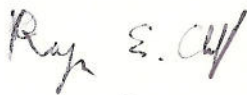
recommended national criterion." Thus EPA has already responded to CBD on the sufficiency of state marine pH criteria.

- API understands the intention of an aragonite saturation index water quality criterion, but believes the implementation of such a criterion would be extraordinarily complex and costly, while resulting in little environmental benefit. The aragonite saturation index varies by location in the ocean, making consistent, accurate monitoring extremely difficult. The translation from an aragonite saturation index to a pH limit for local dischargers, as would be required if a water is listed as impaired for this criterion, depends greatly on local chemistry and would be a complex if not impossible task. Moreover, ocean acidification is already directly measured by pH, a parameter for which monitoring programs and marine criteria and standards already exist.
- API supports EPA's proposal to establish a technical workgroup to review existing scientific information about ocean acidification and guide future policy decisions. API strongly recommends that this workgroup conduct its research and proceedings in an open, transparent and collaborative manner, including public stakeholder meetings to solicit input from industry and the general scientific community.

In summary, API urges EPA to deny CBD's petitions, and continue its work in an open, transparent process to address critical data gaps, noting that ocean acidification is a complex global issue requiring a complex and global response, well beyond the scope of the CWA.

API's detailed comments are attached to this letter. API appreciates the opportunity to provide these comments. Please feel free to contact me if you have any questions about API's comments, or wish to discuss them further with us.

Sincerely,



Roger E. Claff, P. E.
Senior Scientific Advisor

cc: P. Tolsdorf, API
A. Emmert, API
B. Ehimika, API

**AMERICAN PETROLEUM INSTITUTE
DETAILED COMMENTS ON CENTER FOR BIOLOGICAL DIVERSITY
OCTOBER 18, 2012 AND APRIL 17, 2013 PETITIONS CONCERNING
OCEAN ACIDIFICATION**

API and its members are aware of EPA's substantial and long-term efforts to better understand, and respond to, ocean acidification. When faced with data gaps, monitoring and control technology limitations, and regulatory options unsuited to the scale and breadth of the alleged causes of ocean acidification, EPA took appropriate steps to begin to understand the data gaps, quantify limitations, and inventory its statutory authority. API has supported these reasonable efforts in previous comments.² The detailed comments that follow continue that support, and take exception to CBD's demand that EPA abandon its reasoned approach.

A. Ocean Acidification is a Complex Global Issue that Cannot be Addressed Through Discrete Localized Regulation

"Ocean acidification" refers to the decrease in the pH of the oceans caused by the uptake by seawater of CO₂ from the atmosphere.³ More precisely, once dissolved in seawater, CO₂ reacts with water to form the bicarbonate ion, HCO₃⁻ (a weak base) and to yield the H⁺ ion (proton)⁴. Seawater (from the surface down to a depth that varies with local conditions) is naturally supersaturated with a related stronger base, the carbonate ion (CO₃²⁻), which acts as a buffer by neutralizing some of the protons forming more bicarbonate ions. The net reaction is: CO₂ + H₂O + CO₃²⁻ → 2HCO₃⁻.⁵ As not all of the protons from the initial CO₂ absorption reaction are so neutralized, the local proton concentration increases and the local ocean pH slightly declines as a result. The magnitude of these chemical changes depends on local conditions, varying with depth, distance from shore, temperature, local seawater chemistry, atmospheric CO₂ concentration, and other factors such as seawater mixing patterns. These are the basic processes and principles of ocean acidification chemistry.

According to EPA and CBD, the primary cause of ocean acidification is increased atmospheric CO₂ concentrations from anthropogenic CO₂ emissions.^{6, 7} As all CO₂ emissions intermix freely in the atmosphere and, regardless of the location of the emission point, contribute to the overall global atmospheric CO₂ concentration, actual or modeled decreases in ocean pH are the cumulative result of all individual stationary and mobile source emissions, as well as all natural source emissions, from every nation in the world. A CO₂ source on the shore of Puget Sound has no more or less potential to harm oysters in the Sound than a source in Sichuan Province, China.

² API letter in response to Ocean Acidification and Marine pH Water Quality Criteria NODA, June 15, 2009; API letter in response to Notice of Call for Public Comment on 303(d) Program and Ocean Acidification, May 14, 2010

³ Memorandum from Denise Keehner, Director, Office of Wetlands, Oceans, Watersheds, USEPA to Water Division Directors, Regions 1-10, entitled, "Integrated Reporting and Listing Decisions Related to Ocean Acidification." Nov. 15, 2010 ("2010 EPA Memo").

⁴ A small fraction of the dissolved CO₂, about 0.12 percent on a molar basis in seawater, reacts with water to form carbonic acid, H₂CO₃. In equilibrium calculations, convention is to consider non-ionized CO₂ as the sum of dissolved CO₂ and non-dissociated H₂CO₃, which reacts with water forms HCO₃⁻ as noted.

⁵ <http://theotherco2problem.wordpress.com/what-happens-chemically/> (accessed 12/11/2013).

⁶ 2010 EPA Memo at 1.

⁷ 2012 Petition at 10; 2013 Petition at 4.

Even if the source on Puget Sound, and thousands like it across the U.S. were able to reduce their CO₂ emissions to zero, subsequent future global increases in CO₂ might well make up the difference in which case the current trend of ocean acidification would resume.

Interestingly, in a recent legal action that was defended by EPA and other federal agencies, two citizens groups sued the federal government to reduce all domestic CO₂ emissions by six percent per year until global atmospheric concentrations of CO₂ fell to 350 parts per million (ppm).⁸ Unlike CBD's petitions, which seek to address ocean acidification through the CWA, plaintiffs in *Alec L. v. Jackson* argued that EPA and the other federal agencies should address global atmospheric concentrations of CO₂ by exerting regulatory control over all domestic CO₂ sources and all aspects of the domestic economy. As such, defendants and interveners in that action were forced to provide evidence on how an annual six percent reduction in domestic CO₂ emissions (even assuming statutory authority to control all sources of CO₂) would impact global atmospheric concentrations of CO₂, and, if the U.S. were able to make such drastic annual reductions, their impact on the U.S. economy.

Expert declarations submitted by interveners, and attached hereto as Exhibits A and B, showed that even if the U.S. were to reduce CO₂ by an astounding six percent per year between 2013 and 2050, such measures "would result in a reduction of approximately 155.2 gigatonnes, which is only 11.8% of the required reduction to achieve the 350 ppm pathway."⁹ In other words, in order to reduce global atmospheric CO₂ concentrations (and address the presumed leading cause of ocean acidification), 88.2 percent of CO₂ reductions would need to come from international sources.

Even though, under this scenario, the drastic six percent annual domestic reductions do not stem the global increase in atmospheric CO₂ concentration, such reductions are estimated to come at great cost to our economy. Indeed, these reductions "would lead to the loss of more than \$15.5 trillion in economic output, measured by the discounted net present value of gross domestic product (GDP) between now [Nov. 2011] and 2050. The average household would experience a reduction of about \$730 in real income in 2015 and \$3900 in 2050."¹⁰

As such, even under the wildly hypothetical scenario wherein the U.S. imposes extreme domestic CO₂ reduction requirements at great cost to its economy, international emissions will more than sustain the growth of atmospheric CO₂ concentrations, and those concentrations' effect on ocean acidification will remain. The complexity inherent in a phenomenon caused in part by cumulative CO₂ emissions across the globe is staggering – even more so considering that atmospheric CO₂ concentration is but one of the many variables that impact oceanic pH levels. Other potential causes of ocean acidification include upwelling of CO₂-rich deep ocean waters, underwater vents of CO₂, biological respiration activities, and the effects of river plumes and other land-source impacts in coastal waters. In specific locations, almost none of these inputs are fully characterized nor well understood.

⁸ *Alec L. v. Jackson*, No. 3:11-CV-02203-EMC (D.D.C., May 31, 2012).

⁹ Exhibit A. Messner Declaration at 9.

¹⁰ Exhibit B. Dr. Montgomery declaration at 2.

Even if all the drivers of ocean acidification were understood and could be reasonably quantified, this global problem manifests in highly-localized, widely-varying changes in pH. Again, many of the variables that contribute to local near-shore pH levels (including temperature, pressure, salinity, depth, nutrients, dissolved oxygen, photosynthesis and respiration, *etc.*) have been identified, but a comprehensive, quantitative understanding of the interrelationships of such parameters has proven beyond the current grasp of science.

Further, even if we could allocate and quantify all the causes of ocean acidification, and even if we could quantify all the local variables that contribute to local decreases in pH, we would still need to understand how such potential decreases impact species in that local water body, in order to develop sound site-specific water quality criteria. The scientific effort to assess these organism impacts is fairly new and current data are limited.

Such limited understanding of the factors that drive pH levels at the local scale and the marine ecosystem impacts therefrom are especially relevant because CBD has petitioned for action under the section of the CWA that is triggered by a finding of localized impairment.¹¹ While ocean acidification impacts may manifest in a highly variable and localized manner, the causes of, and potential remedies for, ocean acidification are overwhelmingly global, highly complex, and, at best, our understanding of such is in its infancy.

B. The CWA is Not Suited to Address Ocean Acidification

As noted above, ocean acidification is a complex global issue that is largely driven by the collective CO₂ emissions of a modern industrialized world. The relief sought by CBD's petitions fails to account for the nature, quantity, and global range of the emission sources that cause ocean acidification.

The CWA is an unsuitable mechanism for addressing the diffuse causes of ocean acidification because of its jurisdictional limitations. The CWA is generally structured to address local water quality impacts by establishing baseline water quality criteria for waterbodies which, if not met, trigger determinations of impairment and imposition of water-quality-based discharge limitations. Water quality criteria are developed by EPA and used by the states to establish water quality standards for individual waterbodies.¹² Water quality standards consist of three components: (1) the designated uses that waterbody is intended to serve; (2) a qualitative (narrative) or numeric standard in order to preserve the waterbody for its intended purpose; and, (3) antidegradation requirements.¹³ Where water quality standards are not being met, the waterbody is identified as impaired. In such cases, the CWA generally requires states to establish total maximum daily loads ("TMDL") for each pollutant causing the waterbody to be impaired.¹⁴ Using TMDLs, states attempt to budget the pollution inputs into the waterbody so that it can meet applicable water quality standards.¹⁵

¹¹ CWA §303.

¹² CWA §303.

¹³ CWA §303(c)(2)(A); 40 C.F.R. § 131.

¹⁴ CWA §303(d)(1)(A).

¹⁵ CWA §303(d).

Because the NPDES permitting program is triggered by discharges, Congress extended the NPDES Permitting requirements as broadly as possible to “the territorial sea, the waters of the contiguous zone, [and] the oceans.”¹⁶ This delineation has been interpreted to require NPDES permits to the furthest extent of U.S. jurisdiction - the 200 mile Exclusive Economic Zone (“EEZ”).¹⁷

In contrast, because CWA Section 303 is triggered by impacts on waterbodies, Congress narrowly constrained jurisdiction to “waters of the United States.” While the phrase “waters of the United States” has been the subject of a great deal of nuanced interpretation and litigation, those aspects of the debate center around which potentially isolated inland and intra-state waters are covered by the CWA. There is no such debate with respect to the ocean. CWA Section 303 jurisdiction extends only to the extent of the “Territorial Sea,” which is defined as the belt of the seas measured from the line of ordinary low water along the portion of the coast which is in direct contact with the open sea and the line marking the seaward limit of inland waters, and extending seaward a distance of three miles.”¹⁸

Congress acted purposefully in limiting Section 303 jurisdiction over the ocean as narrowly as possible – 197 miles short of its full authority. Section 303 was designed to be driven by local, not global, impacts; the impacts with which Congress was concerned were those close to the shore – “the Nation’s waters.”¹⁹ Significantly, despite amending the CWA 12 times since 1989, Congress never extended the Section 303 jurisdiction beyond three miles.²⁰ Section 303 was and is clearly designed to address local impairment – not worldwide impairment.

Certainly, there is some appeal to a regulatory approach that neatly provides brightly defined baseline criteria for waterbodies that, when violated, trigger discharge limitations and regulatory constraints to fix the problem and restore the waterbody. Notwithstanding the appeal of such an approach, however, TMDLs developed under the CWA to restore compliance with local water quality standards possibly budget but do not constrain either local or global air emissions; TMDLs are further constrained by limits of authority of the local jurisdictions where the impaired waterbody resides and cannot address wider regional or global sources. Section 303 is therefore not an appropriate method to address ocean acidification.

1. *EPA Lacks Statutory Authority under the Clean Water Act to Regulate CO₂ Emissions*

CBD’s two central assumptions underlying its petitions to the EPA are: (1) that reducing man-made CO₂ emissions is a necessary step to slow or halt ocean acidification; and (2) that the CWA provides the EPA with the necessary statutory authority to control CO₂ emissions. Even if

¹⁶ CWA §402(a)(1) and 403.

¹⁷ See Mathews, Joe. “Redefining the Territorial Sea in the Clean Water Act: Replacing Outdated Terminology and Extending Regulatory Jurisdiction.” *Sea Grant Law and Policy Journal*, Vol.4, No. 1 (Summer 2011). P. 121 (“Mathews (2011)).

¹⁸ CWA §502(8).

¹⁹ CWA §101(a).

²⁰ PL 101-144(Nov. 9, 1989); PL 101-380(Aug. 18, 1990); PL-101-596 (Nov. 16, 1990); PL 102-104 (Aug. 17, 1991); PL 102-240 (Dec. 18, 1991); PL 102-389 (Oct. 6, 1992); PL 102-580 (Oct. 31, 1992); PL 104-66 (Dec. 21, 1995); PL 104-106 (Feb. 10, 1996); PL 104-208 (Sept. 30, 1996); PL 104-303 (Oct. 12, 1996); PL 104-324 (Oct. 19, 1996).

CBD's first assumption is right, its second assumption is wrong. The CWA does not provide EPA with statutory authority to control CO₂ emissions. This is because, in part, CO₂ is not a "pollutant" discharged to jurisdictional waters under the CWA.

Under the CWA, the term "pollutant" is defined as:

Dredged spoil, solid waste, incinerator residue, sewage, garbage, sewage sludge, munitions, chemical wastes, biological materials, radioactive materials, heat, wrecked or discarded equipment, rock, sand, cellar dirt, and industrial, municipal, and agricultural waste discharged into water.²¹

The materials listed within the CWA "pollutant" definition hardly encompass – or even resemble – CO₂, a gas that is both naturally occurring and essential to support life on our planet. Nor do airborne CO₂ emissions fall within the CWA's limitation in the definition of "pollutant" to those substances "discharged into water." The CWA defines "discharge of a pollutant" to include:

- (A) Any addition of any pollutant into navigable waters from any *point source*,
- (B) Any addition of any pollutant to the waters of the contiguous zone or the ocean from any *point source* other than a vessel or floating craft.²²

The term "point source" is also defined as:

Any discernible, confined and discrete conveyance, including but not limited to any pipe, ditch, channel, tunnel, conduit, well, discrete fissure, container, rolling stock, concentrated animal feeding operation, or vessel or other floating craft, from which pollutants are or may be discharged.²³

The CWA clearly constrains the definition of a "pollutant" to those materials that are discharged, and the CWA further constrains the definition of "discharge" as those that enter a jurisdictional water through "discernible, confined and discrete" conveyances. CO₂, however, is emitted into the atmosphere, where it instantaneously mixes with existing CO₂ in the atmosphere. In this regard, CO₂ is quite different from airborne pollutants, like mercury, subject to atmospheric deposition.²⁴ Even if CO₂ could be characterized as an "industrial, municipal, and agricultural waste," which API does not concede, it still does not meet the CWA's definition of "pollutant"

²¹ CWA §502(6).

²² CWA §502(12) (emphasis added).

²³ CWA §502(14).

²⁴ CO₂ emissions do not cause impairment principally through deposition but rather through absorption. Deposition entails the settling onto water bodies of pollutants adsorbed to particulate matter, either as dry particles or captured by rainfall, or of pollutants dissolved in rainwater. CO₂ indeed dissolves in rainwater, reacts with rainwater, and is deposited by this mechanism; however, more importantly CO₂ as an atmospheric gas is directly absorbed by seawater, and reacts with seawater, as the concentration of CO₂ in the atmosphere equilibrates with that dissolved in the ocean.

because CO₂ is not “discharged into water” from a “discernible, confined or discrete conveyance.”

2. *Even if Jurisdictional Waters are Impaired Under Section 303(d) of the CWA, the Section 303 Program Does Not Regulate Air Emissions*

The principal tools available under the CWA to EPA and state water agencies to address impairment issues and to meet TMDL requirements under Section 303(d) are the imposition of maximum daily loads on point sources under the NPDES program and reductions from nonpoint sources. Reductions from nonpoint sources, however, are strictly voluntary. As such, even if CO₂ were considered a pollutant subject to control under the CWA, the fact that it is released as an air emission precludes it from being controlled through a TMDL allocation. The U.S. General Accounting Office (“GAO”), examining the utility of water quality criteria and TMDLs to address closely analogous air deposition issues, summed up the regulatory mismatch quite well:

... but the CWA does not directly regulate nonpoint sources of pollution, including pollution resulting from atmospheric deposition. When states identify waterbodies that are impaired--that is, that do not meet CWA water quality standards with existing controls--the CWA requires states to formally identify them as impaired, and generally to set a TMDL for each pollutant that does not meet the standards. TMDLs are not self-implementing and CWA does not expressly require they be implemented; states generally have the lead role for implementation. TMDL allocations for permitted point sources are typically implemented via NPDES permits. Relevant NPDES permits issued to facilities for point sources of that pollutant must be consistent with the allocations established by the TMDL, *but there is no comparable permitting mechanism under the CWA directly limiting pollutants from nonpoint sources.*²⁵

Although TMDLs are not suited for this purpose, there have been some limited instances where states have attempted to address nonpoint airborne emissions to satisfy the limits in related TMDLs.²⁶ Those instances, however, differ from ocean acidification through CO₂ absorption in that they involved atmospheric deposition of substances such as mercury, the emissions of which bore a regional nexus to the impaired waterbody.²⁷ Moreover, even in these limited instances,

²⁵ GAO report number GAO-13-39 *Water Quality: EPA Faces Challenges in Addressing Damage Caused by Airborne Pollutants*, GAO-13-39 (Feb. 25, 2013), available at <http://www.gao.gov/assets/660/652294.txt>. (“GAO Air Deposition Report”)

²⁶ See *id.*

²⁷ See Northeast Regional Mercury TMDL Fact Sheet: <http://www.neiwpcc.org>. See also GAO Air Deposition Report noting that coal-fired power generation is the primary source of mercury emissions and that “local sources can be the dominant contributor of mercury atmospheric deposition in areas where there are sources that emit large amounts of mercury.” GAO Air Deposition Report at 20. See also EPA Air Deposition Handbook discussing “Airsheds” Available at http://water.epa.gov/lawsregs/lawsguidance/cwa/tmdl/upload/2003_07_02_airdeposition_airdep_sept_final.pdf. See also Minnesota Mercury TMDL noting that 99.5% of mercury from atmospheric deposition and 93% in-state

the states did not rely on the CWA as their basis for asserting jurisdiction over air emissions. Nor could they, since the CWA simply does not provide statutory authority to regulate air emissions.

3. *Even If Jurisdictional Waters are Impaired Under Section 303(d) of the CWA, a TMDL Would Not be Warranted*

EPA encourages states to use a five-category system for classifying water bodies (or segments) as impaired.²⁸ We agree with EPA that states should utilize Category 3 of the Integrated Report (IR) Guidance “for segments where there is insufficient data and/or information to make a determination related to OA.”²⁹ Indeed, given the data gaps discussed throughout these comments, we believe that Category 3 determinations are appropriate for most near shore segments with high pH variability.

Assuming that the many data gaps could be addressed to such an extent that states could credibly determine that near shore segments failed to meet water quality standards for pH, TMDLs would still not be warranted because “the failure to meet an applicable water quality standard is not caused by a pollutant, but instead is caused by other types of pollution.”³⁰ In these situations, the IR Guidance allows the waterbody to be listed under Category 4C, but does not require imposition of a TMDL.³¹

“Pollution” is defined by the CWA as “the man-made or man-induced alteration of the chemical, physical, biological, and radiological integrity of water.”³² The IR Guidance lists “stream channelization” leading to inadequate flow as such a man-made alteration.³³ Additionally, several states have utilized Category 4C for invasive species,³⁴ dam impingement and entrainment,³⁵ “habitat alternations,”³⁶ and “navigation development.”³⁷

While ocean acidification is arguably not “pollution” because EPA views its causes as both anthropogenic and natural, air emissions of CO₂ are certainly not within the CWA’s definition of “pollutants.” As such, if states are able to determine that near shore segments failed to meet water quality standards for pH, Category 4C is the best option because it does not force states to

reductions in mercury emissions required to address impairment.

<http://www.pca.state.mn.us/index.php/water/water-types-and-programs/minnesotas-impaired-waters-and-tmdls/tmdl-projects/special-projects/statewide-mercury-tmdl-pollutant-reduction-plan.html>

²⁸ Guidance for 2006 Assessment, Listing, and Reporting Requirements Pursuant to Sections 303(d), 305(b) and 314 of the Clean Water Act; EPA Office of Water (July 29, 2005) (“IR Guidance”)

²⁹ 2010 EPA Memo at 9.

³⁰ IR Guidance at 56.

³¹ *Id.*

³² CWA §502(19).

³³ IR Guidance at 56.

³⁴ The Role of Aquatic Invasive Species in State Listing of Impaired Waters and the TMDL Program: Seven Case Studies, Environmental Law Institute (May 2008). See also <http://www.dem.ri.gov/programs/benviron/water/quality/pdf/iwqmon12.pdf>

³⁵ July 29, 2009 letter from Acting Director Earl W. Pabst to William A. Spratlin, EPA Region 7, “Submittal of Lake of the Ozarks (Water Body ID: 7205) for Category 4C of Missouri’s 2008 Water Quality Report”

³⁶ Iowa 2008 Impaired Waters Report

³⁷ *Id.*

impose TMDLs where they will not be effective. Indeed, states have very recently asked EPA to preserve flexibility for those “water/pollutant combinations . . . [for which] there is no means to address the problem through traditional TMDL, permitting, or enforcement processes.”³⁸ The need to address situations where impairment is not caused by pollutants and the need to develop alternative to TMDLs was a cornerstone of EPA’s recent Long-Term Vision for Assessment, Restoration, and Protection under the Clean Water Act Section 303(d) Program.³⁹ Potential utilization of Category 4C where near shore segments can be shown to be impaired for pH would be an appropriate embodiment of EPA’s vision.

C. EPA Should Deny the Relief Requested in CBD’s 2012 Petition

CBD’s 2012 Petition called on EPA to promulgate water quality standards for 15 states and territories whose existing water quality standards do not meet federal water quality criteria for marine pH.⁴⁰ The allegedly unmet federal water quality criteria allow a “pH range of 6.5 to 8.5 for marine aquatic life, but not varying more than 0.2 units outside the normally occurring range.”⁴¹ According to CBD, the 15 states and territories failed to meet the federal water quality criteria because they allowed for different ranges or deviations greater than 0.2 units outside of the normally occurring range.⁴² This petition follows CBD’s December 18, 2007 Petition to EPA to establish water quality criteria to prohibit any measurable deviation from the naturally occurring pH range, CBD’s petitions to the same states and territories to revise their water quality standards, and a CBD lawsuit against EPA for approving Washington State’s 2008 303(d) list.⁴³

1. *States Have Broad Discretion in Setting Water Quality Standards and EPA has Broad Discretion in Reviewing and Approving Such Standards*

The CWA provides a mechanism to delegate to states primacy in controlling water pollution.⁴⁴ All states but four (Massachusetts, New Hampshire, New Mexico, and Idaho, plus the District of Columbia) have been delegated full or partial primacy in implementing the NPDES program. While the states and EPA share duties relative to addressing impaired waterbodies, primary responsibility for establishing appropriate water quality standards is left to the states.⁴⁵ Indeed, as noted by EPA, the Section 303 program is “primarily State-led with EPA oversight.”⁴⁶

³⁸ Reducing Reporting Burden under Clean Water Act Sections 303(d) and 305(b): Final Report, EPA (Feb. 2013).

³⁹ <http://water.epa.gov/lawsregs/lawsguidance/cwa/tmdl/programvision.cfm> (Dec. 12, 2013).

⁴⁰ Those states are Alabama, Connecticut, Delaware, Guan, Hawaii, Maine, Maryland, Mississippi, North Carolina, Northern Mariana Islands, Oregon, Puerto Rico, Virginia, and Washington. CBD’s 2012 Petition at 5.

⁴¹ Gold Book, Quality Criteria for Water, USEPA (1986).

⁴² CBD’s 2012 Petition at 5.

⁴³ *CBD v. EPA*, No. 2:09cv670 (W.D. Wash).

⁴⁴ See, e.g., *Chevron, U.S.A. Inc. v. Hammond*, 726 F.2d 483, 489 (9th Cir.1984), cert. denied, 471 U.S. 1140 (1985).

⁴⁵ See *id.* (citing § 1251(b) (1982)); *Chevron U.S.A., Inc. v. Hammond*, 726 F.2d 483 (9th Cir.1984), cert. denied sub nom. *Chevron U.S.A. Inc. v. Sheffield*, 471 U.S. 1140 (1985); *District of Columbia v. Schramm*, 631 F.2d 854 (D.C.Cir.1980).

⁴⁶ EPA’s Questions and Answers on Ocean Acidification and the Clean Water Act 303(d) Program (Nov. 15, 2010) at 1.

Under the CWA, states, through public processes, promulgate their own water quality standards based on the designated uses of the waterbody, an accounting for public health and welfare, and with a goal of enhancing the quality of the waterbody.⁴⁷ In basing their standards on the designated uses of the waterbody, states are free to consider the appropriate federal water quality criteria for such uses, or any “other scientifically defensible methods.”⁴⁸ Far from requiring states to establish water quality standards that are exactly the same as the federal water quality criteria (as suggested by CBD), Section 303 provides states substantial flexibility in establishing their own unique water quality standards so long as the basis for such standards is stated and defensible. Such flexibility is a key component of the “State-led” approach provided by Congress in the CWA, and is particularly relevant to ocean acidification. As discussed further below, the spatial and temporal variability of oceanic pH levels – particularly in the near-shore areas covered by Section 303 – as well as monitoring limitations and a lack of recognized baselines for coastal pH makes the 15 states’ modest deviation from the federal water quality criteria entirely defensible.

EPA sits in a reviewing capacity of the state-implemented standards, with approval and rejection powers only.⁴⁹ The sole function in EPA’s reviewing capacity is to determine whether the States’ decision is scientifically defensible and protective of designated uses.⁵⁰ Consistent with that role, and in consideration of the data gaps and technological limitations inherent in establishing pH standards in coastal waters, EPA appropriately approved the water quality standards in each of these states and, in 2010, reiterated that “[c]urrently all 23 coastal States and five Territories . . . have marine pH water quality criteria in place that are similar to EPA’s CWA 304(a)(1) recommended national criterion”⁵¹ The memorandum was issued as a condition of the settlement between EPA and CBD over CBD’s lawsuit concerning the state of Washington’s 2008 impaired water list. Thus EPA drew this conclusion after careful examination of the state marine pH standards, in direct response to CBD’s legal action concerning ocean acidification. EPA is clearly satisfied with the existing state standards.

Even if CBD were correct that state water quality standards were not permitted to deviate from federal water quality criteria, EPA has already determined that the 15 state standards do not deviate from the federal water quality criteria, and therefore approved them – actions for which EPA is entitled to deference.⁵² The NRDC case cited by CBD in the 2012 Petition is instructive in this respect.

That action involved a challenge to EPA’s approval of state water quality standards that contained a 5,000-fold bioconcentration factor (BCF) in fish. Despite noting the existence of evidence suggesting that the standard was not sufficiently protective, the court found that EPA’s approval was entitled to deference:

⁴⁷ CWA § 303(c)(1).

⁴⁸ CWA § 303(c)(1); 40 C.F.R. § 131.11.

⁴⁹ *Id.* at 1401 (citing 40 C.F.R. §§ 131.5(a), 131.6(c), 131.11(a) & (b)); See also EPA’s opening brief in *Gulf Restoration Network v. McCarthy* (No. 12-cv-00677 (5th Cir.) at p. 23 (articulating and defending EPA’s limited oversight role).

⁵⁰ *Id.*

⁵¹ 2010 EPA memo at 4.

⁵² *NRDC*, 16 F.3d at 1399 ; see also *Shanty Town Assocs. Ltd. v. EPA*, 843 F.2d 782, 790 (4th Cir.1988).

Once again, we are confronted with an area dominated by complex scientific inquiry and judgment. The Court found that, although EPA was aware that some recent BCF studies suggested a higher BCF than 5000, EPA maintained that such results were inconclusive and that no compelling scientific evidence indicated that a 5000 BCF is no longer within the range of scientific defensibility. The Court simply was “not in a position to second-guess this technical decision by administrative experts.”⁵³

In summarizing its holding, the Court continued,

We find that EPA's review of the Maryland and Virginia water quality standards was neither arbitrary nor capricious. Each review conducted by EPA was supported by lengthy, highly scientific, technical support documents explaining in detail EPA's rationale in approving the 1.2 ppq standards. EPA has satisfied this court that substantial evidence exists in the administrative record to support its decision, and that it acted rationally and in accordance with the CWA and its regulations. We therefore refuse to upset either EPA's decision to approve Maryland's and Virginia's adoption of the 1.2 ppq standard or the district court decision affirming the same.⁵⁴

CBD also faces a high hurdle in trying to compel EPA to amend existing state water quality standards. Under section 303(c)(4)(B) of the CWA, CBD must establish that a new standard is “necessary” to meet the CWA's requirements. Courts rarely second-guess EPA's decision not to amend existing state water quality standards.⁵⁵

In sum, the CWA gives states substantial discretion in developing water quality standards. EPA, for its part, has substantial discretion to approve such standards and to refrain from imposing its own. CBD characterization otherwise simply has no merit. Further, as noted below, the significant technological limitations and data gaps presented by the ocean acidification issue fully support EPA and the 15 states' determinations. In fact, given these gaps and limitations, and EPA's acknowledgement of such, any rewriting of state water quality standards would be arbitrary and capricious.

2. The Data and Technological Gaps that Impeded EPA's Ability to Establish Stricter Water Quality Criteria in 2010 Remain Unchanged Today

On November 15, 2010, EPA published a finding that “information is largely absent or limited at this point in time to support the listing of waters for OA in many States.”⁵⁶ Specifically with respect to water quality criteria for ocean acidification, EPA noted that:

⁵³ *Id.*

⁵⁴ *Id.* at 1404-05.

⁵⁵ *Id.* at 1401; see also *Shanty Town Assocs. Ltd. v. EPA*, 843 F.2d 782, 790 (4th Cir. 1988).

⁵⁶ 2010 EPA Memo at 1.

the majority of the States do not have detailed monitoring protocols, assessment methods, or the high-resolution equipment needed to measure and implement the marine pH criteria. In particular, in most coastal regions data are not readily available to characterize short-term marine pH diurnal and seasonal variability, or to quantify a normally occurring pH 'baseline' necessary to identify variation from natural and any long term trends . . . After reviewing a wide range of information received in response to a Notice of Data Availability (NODA) on Ocean Acidification and Marine pH water quality criteria . . . , EPA decided against revising the national pH criterion for aquatic life due to insufficient data. .

⁵⁷

Importantly, the data and technological limitations that impeded EPA's ability to revise the national pH criteria in 2010 still exist today and should similarly inform EPA's response to the 2012 Petition's request that EPA impose water quality standards in 15 specific states. In fact, CBD, in its 2013 Petition, not only identified and acknowledges these barriers to stricter pH standards, it uses them as a justification for its demand for new water quality criteria.⁵⁸

In addition to EPA (and CBD itself), numerous states have recognized the continued existence of these barriers. California, Oregon, and Washington, whose water quality standards CBD seeks to invalidate, recently convened an Ocean Acidification and Hypoxia Science Panel to, among other tasks, identify and start to address data gaps.⁵⁹ Not only does this Panel show that impacted states are working to better understand ocean acidification, the questions and data gaps raised at the Panel's inaugural meeting on March 26, 2013 show that the state of ocean acidification science has not appreciably changed since 2010:

What are the natural variations in acidification parameters, such as pH, in both space and time? Aragonite saturation should be included as a measurement in addition to, or in place of pH.

What is our baseline for natural?

What is the time scale to answer this question?

How much do land-based sources of nutrient inputs, such as runoff and wastewater discharge, contribute to local patterns of ocean acidification...?

What biological responses have, or are likely to, occur in response to present trends in acidification...? What biological responses and ecological impacts have already occurred due to past anthropogenic acidification ...?

⁵⁷ 2010 EPA Memo at 4.

⁵⁸ CBD's 2013 Petition at 34.

⁵⁹ <http://calost.org/science-advising/?page=ocean-acidification-and-hypoxia-panel> (accessed 12/9/13).

What research should be conducted to increase confidence in the answers to these questions? Monitoring should be included in this question.

Consider adding this question: What are adaptation options?⁶⁰

It should be kept in mind that the Panel that developed these questions less than 12 months ago had significant input from the research done by NOAA and the State of Washington as reflected in the report developed by the Washington State Ocean Acidification Blue Ribbon Panel.⁶¹ As these widely acknowledged baseline, monitoring, and variability, and biological response issues undermine any credible effort to tighten or change federal water quality criteria or state water quality standards, we discuss each in depth below.

i. Monitoring Limitations

As EPA recently noted, “the majority of the States do not have detailed monitoring protocols, assessment methods, or the high-resolution equipment needed to measure and implement the marine pH criteria.”⁶² Indeed, monitoring is key to understanding the fundamental processes that occur in complex coastal ecosystems. Of those processes, pH is a key variable that needs to be monitored in order to understand carbonate chemistry in such waters. Limitations on the measurement techniques for pH and the ability to achieve precision in such measurements is extremely important. There is some concern, however, that meeting narrow-range water-quality-based pH criteria of ± 0.2 SU may be infeasible with current monitoring technology.

Additionally, defining baseline pH conditions and the potential impacts of ocean acidification requires technology that, as a minimum, has an ability to detect and accurately measure the pH changes that are estimated to be occurring or projected to occur. Widely-cited estimates suggest ongoing pH changes of approximately 0.002 units per year⁶³ - far below what can be routinely accurately monitored through existing technology. Although there are recent developments in more accurate pH measurements using spectrophotometric method, they have not yet been widely deployed in field conditions.⁶⁴ Important additional considerations relative to the technological limitations of monitoring include the following:

- *Importance of proper field controls, including proper temperature control.* Temperature and contact with atmospheric CO₂ can affect the measured pH.⁶⁵ Therefore,

⁶⁰ *Id.*

⁶¹ Ocean Acidification: From Knowledge to Action, WA State’s Strategic Response: <https://fortress.wa.gov/ecy/publications/SummaryPages/1201015.html> (accessed 12/6/2013).

⁶² EPA 2010 Memo at 4.

⁶³ Friis, K., et. al., Spectrophotometric pH measurement in the ocean: Requirements, design, and testing of an autonomous charge-coupled device detector system *Limnol. Oceanogr.: Methods* Vol. 2, 2004, p. 126–136 “[T]he increase of surface water pCO₂ due to the uptake of atmospheric pCO₂ drives a pH decrease of about 0.002 pH units per year (at constant alkalinity). The required analytical accuracy of seawater pH measurements is therefore of the same order.”

⁶⁴ Abmann, S., et. al., Spectrophotometric high-precision seawater pH determination for use in underway measuring systems, *Ocean Sci.*, Vol. 7, p. 597–607, 2011.

⁶⁵ Because pH is dependent upon temperature, the temperature of the pH sample must be carefully controlled, or at least accurately measured before pH is determined. In addition, the pH of a seawater sample changes as CO₂ is lost

proper field controls are essential. The effectiveness of field controls, and therefore the resulting precision and accuracy achieved by even the limited current field data are unknown;

- *Process Control System Limitations.* System "dead time" for feedback signal transmission and response; also sluggish response times for control valves and base pumps;
- *Electrode Limitations.* Limited calibration range for electrodes of ± 0.1 SU; also electrode "memory" causing sluggish response; and,
- *Flow Rate Variability Limitations.* Variability in flow rate and detention time necessitates hydraulic equalization, which may be infeasible; also neutralization of large flows invites mixing dead zones and pH "short-circuiting" past the mixer.

It is simply infeasible to require standards with ranges so narrow that the deviation from such cannot be accurately monitored, or in the case of NPDES compliance, controlled. These monitoring limitations, however, are even more pronounced when monitoring is used to measure changes from baseline pH conditions that are not presently understood in waterbodies that experience significant temporal and spatial pH variability, in order to gauge the largely unstudied biological responses to such changes. These baseline, variability, and response issues are discussed below. As determined by EPA in 2010, together, these issues present a clear impediment to the imposition stricter water quality criteria and standards.

ii. Daily/Hourly Variability

In addition to the inability to accurately monitor pH in real-time at the level necessary to identify deviations from a strict water quality criteria or standards, the frequency at which pH can, and does, vary in a waterbody frustrates the establishment of, and adherence to, strict water quality criteria and standards. Indeed, in some waterbodies, pH changes of 0.5 units have been reported within a single day. Judging impairment based on a small deviation from a "natural range" is simply impossible if the "natural range" is mis-calibrated, broader than the criteria or standard's range, and if deviations daily occur that exceed the maximum deviation allowed under such criteria or standards. As all studies of near-shore pH variability have found, pH variability in the near-shore waters makes the federal water quality criteria unworkable and CBD's demand for strict adherence thereto infeasible.

Consider the following results from 24,519 measurements spanning 8 years of observing coastal ocean pH off Tatoosh Island (0.7 km off the northwestern tip of Washington State):

or gained on contact with the atmosphere. This is particularly a concern for samples with low alkalinity, and where dissolved CO₂ concentrations are significantly higher or lower than that which would be in equilibrium with the atmosphere. It is therefore important that samples be drawn as soon as possible after arrival of the rosette on deck. Furthermore, contact with the atmosphere should be avoided during sampling, sample bottles should remain tightly sealed until pH measurements are made, and pH measurements should be made right away. Available at <http://hahana.soest.hawaii.edu/hot/protocols/chap23.html>

First, in contrast to the historical perspective that the ocean is well buffered, pH exhibited a pronounced 24-hour cycle, spanning 0.24 units during a typical day . . . This diurnal oscillation is readily explained by daily variation in photosynthesis and background respiration: water pH increases as CO₂ is taken up, via photosynthesis, over the course of the day, and then declines as respiration and diffusion from the atmosphere replenish CO₂ overnight . . . Second, pH fluctuated substantially among days and years, ranging across a unit or more within any given year and 1.5 units over the study period.⁶⁶

Additionally, NOAA has only recently begun collecting time-resolved data on parameters such as pH and partial pressure of CO₂ (“pCO₂”)⁶⁷ in coastal waters, in addition to a few existing sites in the open oceans.⁶⁸ While its data are less voluminous, its pH measurements are no less variable.⁶⁹ As noted by NOAA:

“In 2010 we began equipping coastal moorings currently measuring pCO₂ with pH and other biogeochemical sensors to measure ocean acidification parameters at 3 hour intervals in the surface water. Here we present the magnitude and diurnal to seasonal variability of pCO₂ and pH during the first year of observations at 2 sites in the Atlantic and Pacific coastal margins of the U.S.: the Gulf of Maine and outer coast of Washington state.”

⁶⁶ Wootton, J.T., Dynamic patterns and ecological impacts of declining ocean pH in a high-resolution multi-year dataset, PNAS, Vol. 105, No. 48, December 2, 2008, 18848–18853.

⁶⁷ pCO₂ is the partial pressure of CO₂ in air, were the dissolved CO₂ concentration in the water under consideration in equilibrium with the air. Since the marine waters under consideration are often not in equilibrium with the air, and hence the concentrations of carbonate species in the marine waters subject to change, pCO₂ is often used as a convenient alternate measurement to that of dissolved CO₂ concentration in marine waters. When atmospheric CO₂ levels rise, pCO₂ typically rises. Along with pH, it is an important parameter for understanding carbonate chemistry in marine ecosystems.

⁶⁸ <http://www.pmel.noaa.gov/co2/story/OA+Observations+and+Data> (Accessed 12/9/2013).

⁶⁹ NOAA’s sampling charts are reproduced in the Appendix to these comments.

Large Variability in Coastal Time-Series

Table 1. Variability in measured surface water pH and pCO₂ (μmol/mol) at Gulf of Maine (CO₂ time-series: May 2006 - April 2011; pH time-series: September 2010 - March 2011), La Push (CO₂ and pH time-series: July 2010 - October 2010), and Station Papa (CO₂ and pH time-series: June 2007 - June 2011). Saturation state of aragonite (Ω_{arag}) is calculated from pCO₂ and pH measurements using CO2SYS (Lewis and Wallace 1998).

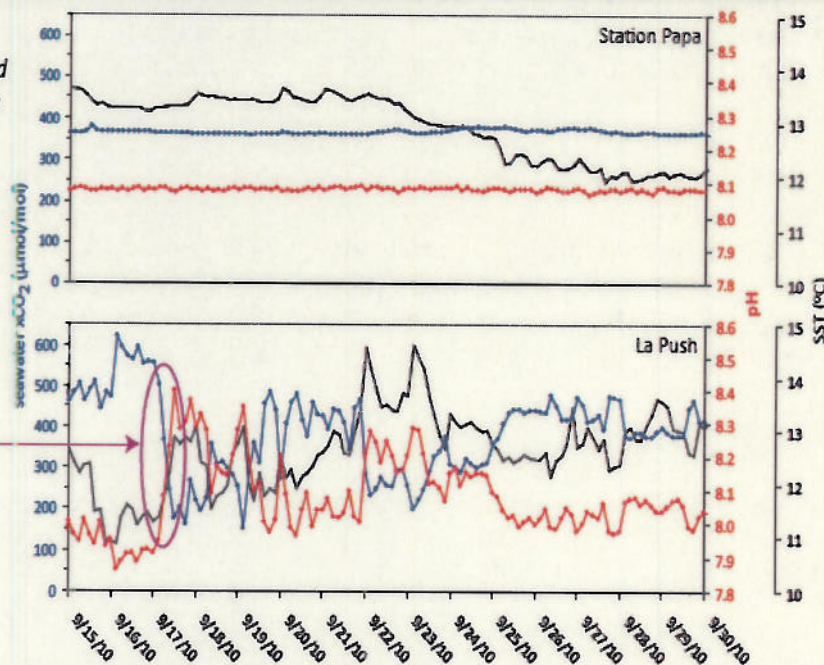
	Gulf of Maine			La Push			Papa		
	Range	Mean	Standard Deviation	Range	Mean	Standard Deviation	Range	Mean	Standard Deviation
pCO ₂ (μmol/mol)	196 - 741	378	57	151 - 621	354	87	314 - 434	372	14
pH	7.98 - 8.18	8.07	0.03	7.86 - 8.40	8.11	0.10	8.01 - 8.15	8.08	0.02
Ω _{arag} (calculated)	1.52 - 2.92	2.03	0.26	1.03 - 7.32	2.46	0.65	1.36 - 2.84	1.93	0.23

Both the magnitude and range of pCO₂ and pH values were greater at the coastal sites (Gulf of Maine and La Push) compared to open ocean Station Papa and also varied between coastal sites (Table 1). The range of pCO₂ and pH values during the coastal time series were as much as 4.5 times the range observed at Papa. We observed pCO₂ and pH values in coastal waters predicted to occur in the open ocean at 2x pre-industrial CO₂ levels . . .

Short-Term Variability at Coastal Sites

Figure 3. Surface water pCO₂ (blue), pH (red), and SST (black) at the Station Papa (top panel) and La Push (bottom panel) moorings during late September 2010. Both panels have the same scale to illustrate the difference in variability.

In a 12-hour period, seawater pCO₂ decreased from ~500 μmol/mol to <200 μmol/mol and pH increased from ~7.9 to 8.4.



Only a few studies in coastal systems have documented short-term variability of carbon chemistry and the factors governing ocean acidification variability (Cullison Gray et al. 2011, Yu et al. 2011).

The largest variance we observed in pH and pCO₂ occurred at the La Push mooring off the Washington coast in September 2010. Values fluctuated as much as 200 uatm pCO₂ and 0.2 pH between 3-hour cycles and >300 uatm pCO₂ and 0.5 pH within one day (Figure 3). Much of the variability at this site is likely due to a combination of high biological productivity and strong winds that can drive localized upwelling. Although seasonal fluctuations are apparent in the Station Papa time-series, values remained stable during this short time period.⁷⁰

Very recently, researchers at Duke University noted that “estuary systems in general and the US East Coast in particular are poorly characterized in terms of the temporal variability of their carbonate systems,” in a study that examined the pH variability in the Beaufort Inlet, in North Carolina.⁷¹ The researchers in Johnson (2013) found that “pH on sub-year time scales exceed the magnitude of long-term projections . . . [0.3 units]”⁷² Johnson (2013) also recorded frequent daily variations of ~0.1 units.⁷³ Other very recent studies of near-shore carbonate chemistry have similarly identified both the short-term pH variability of such systems and the critical need for further research.⁷⁴

In its 2012 Petition, CBD asked EPA to invalidate 15 state water quality standards that allow variations of more than 0.2 units outside a “naturally occurring range” and to impose its own water quality standards.⁷⁵ Given the significant variability of near-shore pH, and the exceptional frequency of such variations, it is impossible to definitively determine a naturally occurring range of pH. Even if such a naturally occurring range could be fixed, it would need to be exceptionally broad to allow for the significant and frequent (sometimes hourly) deviations routinely observed in coastal waters, some of which are driven by variables we understand – many of which are not.

iii. Natural Causes of Ocean Acidity Changes/Variability

There are many factors that affect ocean acidity, of which the oceanic uptake of atmospheric CO₂ is but one. This is especially true in coastal waters where there can be many, site-specific, local, or regional factors. A comprehensive understanding of naturally occurring local or regional contributions to ocean acidification and pH variability is important, but, as noted below, presently lacking:

⁷⁰ Sutton, A.J., *et. al.*, Natural Variability of pCO₂ and pH in the Atlantic and Pacific Coastal Margins of the US, AGU 2011 OS33B-1650.

⁷¹ Johnson ZI, Wheeler BJ, Blinberry SK, Carlson CM, Ward CS, et al. (2013) Dramatic Variability of the Carbonate System at a Temperate Coastal Ocean Site (Beaufort, North Carolina, USA) is Regulated by Physical and Biogeochemical Processes on Multiple Timescales. PLoS ONE 8(12): e85117 (published Dec. 17, 2013).

⁷² *Id.*

⁷³ *Id.*

⁷⁴ Waldbusser GG, Salisbury JE (2014) Ocean Acidification in the Coastal Zone from an Organism’s perspective: Multiple System Parameters, Frequency Domains, and Habitats. Annual Review of Marine Science Vol. 6:221-247 (Jan. 2014); Hoffman et al. (2014) Exploring Local Adaptation and the Ocean Acidification Seascape – Studies in the California Current Large Marine Ecosystem. Biogeosciences 1153-1164 (Feb. 24, 2014).

⁷⁵ 2012 Petition at 1.

The effect of Ocean Acidification (OA) on marine biota is quasi-predictable at best. While perturbation studies, in the form of incubations under elevated $p\text{CO}_2$, reveal sensitivities and responses of individual species, one missing link in the OA story results from a chronic lack of pH data specific to a given species' natural habitat. . . These observations reveal a continuum of month-long pH variability with standard deviations from 0.004 to 0.277 and ranges spanning 0.024 to 1.430 pH units. The nature of the observed variability was also highly site-dependent, with characteristic diel, semi-diurnal, and stochastic patterns of varying amplitudes.⁷⁶

Hoffman (2014) subsequently noted that “[f]or coastal regions, the scientific community is just now assessing the longer-term variability in pH,” and that, heretofore, “no coordinated inner-shelf time series were available that would allow evaluation of the frequency, intensity and spatial expanse with which coastal ecosystems experience rapid acidification.”⁷⁷

The importance of natural variability is also noted by Hofmann:

Recently, a deeper consideration of ecosystem-specific variation in seawater chemistry has emerged, one that is pertinent to the study of biological consequences of OA. Specifically, assessments of environmental heterogeneity present a nuanced complement to current laboratory experiments. The dynamics of specific natural carbonate chemistry on local scales provide critical context because outcomes of experiments on single species are used in meta-analyses to project the overall biological consequences of OA, to forecast ecosystem-level outcomes, and ultimately to contribute to policy decisions and the management of fisheries. As noted earlier, natural variability in pH is seldom considered when effects of ocean acidification are considered. Natural variability may occur at rates much higher than the rate at which carbon dioxide is decreasing ocean pH, about -0.0017 pH/year. This ambient fluctuation in pH may have a large impact on the development of resilience in marine populations, or it may combine with the steady effects of acidification to produce extreme events with large impacts. In either case, understanding the environmental variability in ocean pH is essential.

Although data on the natural variation in the seawater CO_2 system are emerging, nearly all high-resolution (e.g. hourly) time series are based on $p\text{CO}_2$ sensors, with comparatively few pH time series

⁷⁶ Hofmann GE, Smith JE, Johnson KS, Send U, Levin LA, et al. (2011) High-Frequency Dynamics of Ocean pH: A Multi-Ecosystem Comparison. PLoS ONE 6(12): e28983. doi:10.1371/journal.pone.0028983 (internal citations excluded; emphasis added).

⁷⁷ Hoffman (2014) at 1055.

found in the literature. From a research perspective, the absence of information regarding natural pH dynamics is a critical data gap for the biological and ecological arm of the multidisciplinary investigation of OA.⁷⁸

The state of Washington is also struggling with the complexities of regional pH variability as it works to develop a response to ocean acidification, and has noted that:

[R]egional factors combine with global carbon dioxide emissions to exacerbate the acidification process. Coastal upwelling brings cold, salty water that is rich in carbon dioxide and low in pH to Washington's coast and eventually into the Puget Sound. Nutrient runoff, organic carbon, and local air emissions of carbon dioxide also contribute to acidification, especially in more developed or urbanized regions.⁷⁹

Also in Washington, other researchers have advised:

[P]ay attention to the Columbia River plume....Chemistry in the Columbia River appears to be strikingly different from upwelling in the ocean. It has a unique chemical signature –low alkalinity, high pCO₂, high O₂, low salinity – while upwelling is high salinity, low temperature, high alkalinity, and is very corrosive.....⁸⁰

Still others note additional factors beyond ocean upwelling and river plumes.

[L]ocal sources of acidification change from region to region, which must be considered in monitoring plans: In WA, respiration processes that occur as phytoplankton sink and are re-mineralized can constitute an additional 20% of acidification in the fall and summer months. This is a great example of how sources of acidification can change in space and time. When you get to Southern CA, the amount of acidification caused by local respiration goes down, while the relative contribution of CO₂

⁷⁸ Hofmann GE, Smith JE, Johnson KS, Send U, Levin LA, et al. (2011) High-Frequency Dynamics of Ocean pH: A Multi-Ecosystem Comparison. PLoS ONE 6(12): e28983. doi:10.1371/journal.pone.0028983 (internal citations excluded; emphasis added).

⁷⁹ <http://www.ecy.wa.gov/water/marine/oa/overview.html>

⁸⁰ Meeting Summary, California (and Oregon?) Ocean Acidification and Hypoxia Science Panel, Tuesday, March 26, 2013, Hosted by the California Ocean Science Trust, available at http://calost.org/pdf/science-advising/ocean-acidification-and-hypoxia-panel/Meeting%20Summary_3.26.13_Final.pdf Since the publication of the meeting summary, where Oregon's participation was in question, the State of Oregon has joined the effort, which is now known as the West Coast Ocean Acidification and Hypoxia Science Panel. <http://westcoastoh.org/california-ocean-protection-council-announces-west-coast-ocean-acidification-and-hypoxia-science-panel/>

emissions goes up. Further, these more local spatial and temporal differences are overlaid by larger scale regional differences.⁸¹

In addition to contributions from nutrient runoff, ocean upwelling, which can be highly localized, is an important contributor to local pH levels and the variability of local pH. Feeley and others have recently observed that:

[T]o better understand the extent of this ocean acidification in coastal waters, we conducted hydrographic surveys along the continental shelf of western North America from central Canada to northern Mexico. We observed seawater that is undersaturated with respect to aragonite upwelling onto large portions of the continental shelf, reaching depths of ~40 to 120 meters along most transect lines and all the way to the surface on one transect off northern California. Although seasonal upwelling of the undersaturated waters onto the shelf is a natural phenomenon in this region, the ocean uptake of anthropogenic CO₂ has increased the areal extent of the affected area.⁸²

More recently, a report by the Congressional Research Service noted the role of several natural variables that can affect ocean acidification levels in a localized manner:

All gases, such as CO₂, are less soluble in water as temperature increases. Thus, marine waters near the poles have a much greater capacity for dissolving CO₂ than do ocean waters in the tropics. In addition, dissolved CO₂ is transported into ocean depths at these high latitudes (i.e., deep water formation mechanism) since the lower-temperature waters are of higher density, causing greater convection to occur than happens in the more stratified tropical oceans. If temperature were the only factor affecting the rate of ocean acidification and its impacts on physical and biological features, these impacts might be more likely to occur in marine waters nearer the poles. However, in addition to temperature, other factors modulate the impact of CO₂ on marine waters. Cellular respiration and organic decomposition add CO₂ to seawater, and photosynthesis removes it. Deep oceanic water is enriched in CO₂ due to respiration in the absence of photosynthesis and, when brought to the surface by equatorial currents (i.e., upwelling), can place CO₂-enriched seawater in contact with the atmosphere where it can absorb even more CO₂. Hence, the tropics, and most notably tropical coral reefs, are also vulnerable to near-term effects. An

⁸¹ Meeting Summary, California (and Oregon?) Ocean Acidification and Hypoxia Science Panel, Tuesday, March 26, 2013, Hosted by the California Ocean Science Trust, available at http://calost.org/pdf/science-advising/ocean-acidification-and-hypoxia-panel/Meeting%20Summary_3.26.13_Final.pdf

⁸² Feeley, R. A., et. al., Evidence for upwelling of corrosive "acidified" water onto the Continental Shelf, available at <http://www.pmel.noaa.gov/pubs/outstand/feel3087/feel3087.shtml> (emphasis added).

additional factor is the potential increase in storm activity at higher latitudes, as some climate models suggest. CO₂ and other acidic gasses such as nitrogen dioxide are also dissolved in rainwater. An increase in North Atlantic or western North Pacific storms could significantly accelerate the pH decrease of surface ocean waters in these regions.⁸³

Wootton and collaborators have also studied the impact of multiple factors in attempting to model ocean pH, as shown in the table and discussion below.

Table 1. Best-fit parameters for a model of ocean pH as a function of atmospheric CO₂, physical, and algal parameters

Parameter	Interpretation	Mean	95% C.I.	GR ² *
a	Constant, pH	15.948	31.659, 0.237 [†]	–
b	Change in pH with atmospheric CO ₂ , pH/ppm CO ₂	–20.593	–20.071, –21.114 [†]	29.8
h	Half the amplitude of the diurnal productivity oscillation, pH	–0.113	–0.108, –0.118 [†]	25.3
φ	Phase shift from midnight of diurnal, h	2.380	2.536, 2.223 [†]	
u	Effects of upwelling, pH/(metric tons/sec/100 m coastline)	–0.005	–0.005, –0.005 [†]	24.8
c	Phytoplankton abundance effect, pH-liter/mg chlorophyll	0.201	0.209, 0.192 [†]	13.8
τ	Temperature effect, pH/°C	0.078	0.084, 0.072 [†]	8.9
d	Pacific Decadal Oscillation effect, pH/°C	–0.045	–0.041, –0.049 [†]	2.7
k	Estimated Alkalinity, pH/μmol/kg	14.390	19.247, 9.534 [†]	0.5
s	Salinity effect, pH/ppt dissolved salt	–0.112	–0.074, –0.150 [†]	0.5

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As noted by Wootton describing the results of his study:

Our data demonstrate that ocean pH exhibits strong dynamic patterns over multiple temporal scales, which can be linked to variation in key physical and biological drivers with known mechanistic ties to pH. Across years, pH declined strongly in association with increases in atmospheric CO₂. Over diurnal timescales, pH also showed strong systematic variation as a result of the interplay between uptake of CO₂ via photosynthesis and release of CO₂ via respiration. Ocean pH also exhibited variability at the seasonal time scale, but these patterns were more complex, with some years showing systematic increases and some showing systematic declines. This complexity is linked to annual variability in the seasonal patterns of drivers of pH . . . Two factors tend to increase pH seasonally: atmospheric CO₂ declines during the summer as it is removed by terrestrial photosynthesis, and increased solar radiation tends to increase water temperature, which reduces CO₂ solubility. Two other factors tend to decrease pH seasonally: phytoplankton frequently decline through the summer . . ., reducing photosynthetic CO₂ uptake, and upwelling generally increases through the summer, which brings high concentrations of CO₂, arising from subsurface respiration, to the

⁸³ Upton, H.F., et. al., Ocean Acidification, Congressional Research Service, July 30, 2013, available at <http://www.fas.org/srg/crs/misc/R40143.pdf>. Internal citations omitted.

⁸⁴ Wootton, J.T., Dynamic patterns and ecological impacts of declining ocean pH in a high-resolution multi-year dataset, PNAS, Vol. 105, No. 48, December 2, 2008, 18848–18853.

surface water, and also offsets seasonal increases in water temperature. In general, the effect of upwelling appears to predominate at the seasonal scale, but varies strongly among years.⁸⁵

Researchers studying carbonate system variability in yet another near-shore region (Beaufort Inlet, N.C.) very recently reached similar conclusions on the multiple causes of dramatic pH variability:

In the oligotrophic open ocean, the larger spatial and temporal scales of physical processes in conjunction with the relatively lower biomass and biogeochemical activity including photosynthesis and respiration rates result in relatively small diurnal and annual variation in pH and DIC. Yet in mesotrophic or eutrophic coastal oceans recent observations demonstrate that some ecosystems already experience annual or daily pH and DIC variability that vastly exceeds observed or predicted long-term change in open ocean regions. This dramatic hourly to annual variability in pH in the coastal ocean occurs over a wide range of temporal and spatial scales and encompasses physical and biogeochemical drivers photosynthesis and respiration and tidal mixing of water masses with different fluxes of CO₂ (e.g. benthic, atmospheric, low biomass oligotrophic waters, high biomass mesotrophic waters). In addition to regular annual and daily cycles, episodic weather events increase the flux of fresh water into estuarine systems, and alter the carbonate systems at the land-sea interface over multiple timescales; and this data suggests that coastal ecosystems and organisms already experience significant periodic (annual or diurnal) or episodic variability in pH and DIC.⁸⁶

In sum, available monitoring data have demonstrated that ocean acidification is highly variable with the highest variability in the coastal and near shore region. Scientists studying the ocean acidification issue have been able to identify the presence of some natural processes that contribute to local pH variability, however, they by no means understand all the potential natural or site-specific inputs to local pH variability, nor are they able to allocate or quantify those potential inputs. Given the hyper-localization of pH levels and our lack of understanding of the causes for such, neither states nor EPA have the ambient monitoring data necessary to craft stricter water quality standards. Water quality standards measure “impairment” as a very modest deviation from a “natural pH state.” If a state cannot identify the natural pH state of the waterbody and cannot assess the frequency and extent of routine and natural deviations from that range, it cannot address the anthropogenic impairment Section 303 of the CWA was designed to address. EPA was correct in 2010 when it stated that “information is largely absent or limited at

⁸⁵ Wootton, J.T., Dynamic patterns and ecological impacts of declining ocean pH in a high-resolution multi-year dataset, PNAS, Vol. 105, No. 48, December 2, 2008, 18848–18853.

⁸⁶ Johnson (2013).

this point in time to support the listing of water for OA in many States.”⁸⁷ Nothing has changed that should cause the Agency to alter this conclusion.

iv. Baseline Issues

Establishing proper baseline conditions raises a number of important policy and science issues. Because baseline is the point (or range) denoting “natural” conditions (or a “natural range”) from which a pH deviation (and therefore impairment) is to be measured, it is central to any sort of regulatory compliance scheme. Yet, as the discussion above shows, we have only recently begun to measure pH in ocean waters – and not yet with the precision needed to monitor projected acidification rates. We simply do not know what pH should be in the absence of (significant) anthropogenic inputs and influences, or which time period or range is appropriate for such a baseline. Our understanding of baseline pH is certainly limited for global open ocean conditions. For the complex and dynamic ecosystems found in the coastal waters subject to the Section 303 program, and therefore CBD’s petition, however, establishing credible baseline pH conditions is simply impossible at this time.

As discussed above, there is a general lack of data for even basic parameters such as pH and pCO₂, with sufficient temporal and spatial resolution in the coastal waters of the U.S. This is true for recent data as well as historical data. As also discussed above, not only is the recent dataset very sparse, but, more importantly, what little data has been collected on these basic variables shows that there is tremendous temporal variability even at the single-point coastal locations being monitored. This is not surprising given the wide (and site-specific) variety of phenomena that can cause or contribute to pH and/or pCO₂ changes in specific coastal waters, as discussed earlier. In addition, it is also obvious that coastal waters are not “closed” systems. Instead these waters are in contact with (and therefore exchange with) the open oceans – and therefore have stochastic changes due to diurnal tides, seasonal currents, periodic storms, and other similar phenomena.

Combining all of this, not only is it currently impossible to meaningfully define even recent baseline values for parameters such as pH (and for aragonite saturation, as we discuss later) in specific locations (as would be essential in order to even attempt the kind of CWA regulatory regime envisioned by the CBD), it raises a fundamental question: can a meaningful baseline for, say, pH or pCO₂, or aragonite saturation, ever be established at a specific coastal water zone?

v. Biological Response Uncertainty

Biological response and associated uncertainty in measured response varies greatly by species and stressor, so criteria should not be based on single-stressor studies but rather studies of the effects of multiple stressors in site-specific ambient conditions. In its 2010 memorandum, EPA properly noted the lack of understanding of biological responses to ocean acidification, both generally, and particularly in coastal marine environments.⁸⁸ Of course, such an understanding is fundamental to establishing the impairment that water quality criteria and standards are intended

⁸⁷ EPA 2010 Memo.

⁸⁸ EPA 2010 Memo at 4.

to address. In doing so, the EPA relied upon work by the National Research Council ("NRC"),⁸⁹ which concluded that "[o]verall, the acidification of seawater should prove unfavorable for most calcifying organisms, and this is likely to constitute a major negative effect on the marine biota. But it must be emphasized that despite extensive research efforts, we still have a poor understanding of the mechanisms and regulation of the calcification process in marine organisms."⁹⁰

Similarly, discussing the impact of potential acidification on internal pH control and other metabolic processes, the NRC stated that:

[t]o date, the state of knowledge concerning the effects of decreasing pH and increasing CO₂ on most marine organisms is sparse. Although many of the underlying physiological mechanisms are understood in some detail, knowledge of the metabolic consequences for individual performance remains weak. Understanding is particularly poor concerning the sensitivities of various life stages of marine organisms . . . Even less is known about the cumulative, lifelong effects of a lower pH environment in terms of how it will affect the performance, growth, survival, and fitness of individuals, especially when combined with other likely stressors.⁹¹

The 2010 NRC report also discussed the ecosystem effects of ocean acidification for various potentially vulnerable ecosystems, including coastal ecosystems. At the outset, the NRC recognized the complexity of such coastal ecosystems:

[C]oastal ecosystems exhibit naturally high variability in pH and seawater chemistry due to biological activity, freshwater input, upwelling, atmospheric deposition, and other factors. They are also subject to a diversity of stresses caused by human activities, such as organic matter and nutrient inputs, pollution by toxic organic compounds and metals, acid rain, sea level rise and other climate change effects, and overfishing. The effects of ocean acidification on coastal ecosystems may be small relative to the effects of these natural and human-induced stresses.⁹²

After providing a summary of the literature through 2010, the NRC concluded that:

...existing research in coastal ecosystems, as is the case with other ecosystems, has been focused on individual organisms, not on the population, community, or ecosystem levels. Consequently, it is unknown whether populations sensitive to changes in ocean chemistry will be able to adapt through behavioral or physiological

⁸⁹ EPA 2010 Memo at 4.

⁹⁰ "Ocean Acidification: A National Strategy to Meet the Challenges of a Changing Ocean, the National Research Council (NRC), 2010, p. 36.

⁹¹ NRC, 2010, p. 37-38.

⁹² NRC, 2010, p. 50.

changes. For example, populations with individuals possessing genetic variations that tolerate the expected changes in ocean chemistry may result in higher survival or reproductive success because of more-rapid than-expected adaptation to the new conditions . . . It is not known whether coastal ecosystems that do not currently experience natural hypoxic and low pH events are less susceptible to incremental shifts in regional ocean chemistry due to ocean acidification. Areas along the U.S. eastern seaboard, the Gulf of Maine, and others have weaker oxygen minimum zones and higher pH waters along coastal zones. Organisms inhabiting these ecosystems may tolerate larger shifts in ocean chemistry caused by ocean acidification than those in ecosystems overlying more hypoxic upwelling waters, but this hypothesis requires study.⁹³

In part, to address such uncertainties and data gaps in biological responses, the NRC made several recommendations in its 2010 report. One key recommendation was that "...the National Program should support an adaptive monitoring program to identify biological response variables specific to ocean acidification. In the meantime, measurements of general indicators of ecosystem change, such as primary productivity, should be supported as part of a program for assessing the effects of acidification."⁹⁴

In addition, as part of its recommendation that "federally-funded research on ocean acidification should focus on the following eight unranked priorities" the NRC highlighted the need to "understand the physiological mechanisms of biological responses," "assess the potential for acclimation and adaptation," "investigate the response of individuals, populations, and communities," and "understand ecosystem-level consequences"⁹⁵ – i.e., four of its eight priorities addressed biological responses.

Clearly, the NRC work, properly relied upon by EPA in its 2010 determination, points overwhelmingly to extensive data gaps in our understanding of the biological responses to ocean acidification, especially on coastal species and ecosystems. Further evidence of these biological data gaps are also discussed in a 2011 IPCC document, with extensive U.S. authorship.⁹⁶ Importantly, other studies have noted these data gaps but also found that marine biota seem to be more resilient to ocean acidification than had been previously presumed.⁹⁷

⁹³ NRC, 2010, p. 52.

⁹⁴ NRC, 2010, p. 5.

⁹⁵ NRC, 2010, p. 7.

⁹⁶ IPCC Workshop on Impacts of Ocean Acidification on Marine Biology and Ecosystems, Workshop Report, January 2011. In particular, see the extensive discussion of biological uncertainties discussed in the Synthesis Plenary report IV-2: "Impacts of ocean acidification for individual organisms: the state of knowledge, key uncertainties, and the way forward" and the Synthesis Plenary Report IV-3: "Scaling up to ecosystems: the state of knowledge, key uncertainties, and the way forward"

⁹⁷ Hendriks IE, Duarte CM & Alvarez M (2010) Vulnerability of marine biodiversity to ocean acidification: A meta-analysis. *Estuarine Coastal & Shelf Science*, 86, 157-64 While the meta-analysis of 372 experimentally evaluated responses has been critiqued, it remains the most comprehensive data review of potential biological responses to

None of the extensive data gaps and uncertainties it had identified have been addressed in the roughly two+ years since the NRC report was published. EPA appropriately determined as much when it approved in 2012 Washington and Oregon's 303(d) lists in spite of CBD's demands that EPA disapprove those lists for failure to include waters allegedly impaired by ocean acidification. In doing so, EPA reviewed and assessed the applicability of each of the 173 studies cited by CBD.⁹⁸ With respect to biological response issues, EPA provided detailed responses to CBD on the inability of laboratory and hatchery studies to establish linkages between biological and oceanographic data, and noted the continued need for more information "on the biological condition within the waterbody (e.g., *in situ* field studies documenting the health of aquatic life populations) or laboratory studies that are designed to account for natural variability and ecological complexity within a particular system."⁹⁹

Even more recently, in its answer to CBD's complaint challenging EPA's approval of Washington's and Oregon's 303(d) lists, EPA defended these determinations and, in response to CBD's repeated conclusory statements on multiple marine biota's adverse responses to lower pH, denied "that the information before it was sufficient to make determinations regarding nonattainment with applicable water quality standards."¹⁰⁰

We also have reviewed the recent planning documents and reports on ocean acidification by various federal governmental agencies in the U.S. such as the United State Geological Service, the National Oceanic and Atmospheric Administration, the National Ocean Council, the Interagency Working Group on Ocean Acidification, as well as similar plans and reports by various states such as those on the West and Gulf Coasts. And we agree with EPA, for the most part, none of these entities have begun to address the huge gaps in biological responses, both at the species, and certainly at the ecosystem level, that can link ocean acidification parameters such as pH or pCO₂ to biologic outcomes.

The only exception was a very recent study presented on the website for the West Coast Ocean Acidification & Hypoxia Science Panel ("OAH Panel") that was co-authored by two OAH panelists.¹⁰¹ Importantly, this study was designed to remedy some of the noted bio-response data gaps by studying ocean acidification responses within the California Current Large Marine Ecosystem, where there are multiple biotic interactions that are variable and complex, instead of in laboratories, where pH responses have been studied in isolation and, perhaps, with pH deviations that would not typically be observed in nature. Indeed, the purpose of the research was to address the major questions "regarding whether marine species currently possess functional traits that would allow the tolerance of a changing environment, or whether they will be able to adapt to rapidly changing ocean conditions in the future."¹⁰²

ocean acidification and, at a minimum, demonstrates that the potential biological responses to ocean acidification remain uncertain.

⁹⁸ Appendix A to EPA Answer in *Center for Biological Diversity v. EPA*, Case No. 13-cv-1866 JLR (W.D. Wash. Jan 15, 2014).

⁹⁹ EPA Evaluation of Ocean Acidification Information (Attachment 3 to EPA Answer); EPA Review of Ecology's Analysis of Ocean Acidification Data and Information at 7 (Enclosure 2 to EPA Answer).

¹⁰⁰ *Id.*

¹⁰¹ Hoffman et al. (2014) Exploring Local Adaptation and the Ocean Acidification Seascape – Studies in the California Current Large Marine Ecosystem. *Biogeosciences* 1153-1164 (Feb. 24, 2014).

¹⁰² Hoffman (2013) at 1054.

Hofmann (2014) focused on sea urchins and mussels because, in lab experiments, those two species experienced differing levels of resilience to pH changes (sea urchins were generally resilient and mussels experienced decreased shell growth and strength).¹⁰³ The field studies in the California Current Large Marine Ecosystem found that sea urchins were unaffected by increases in pCO₂ and, surprisingly, adult mussels of the species *Mytilus californianus* showed *increased* growth “at sites with more extreme exposures to pH.”¹⁰⁴

While evidence of resilience is welcome, the results of this study do not come close to addressing the data gaps in biological response.¹⁰⁵ This study was but one step toward addressing these complex responses within their complex environments. Therefore, even if states were able to precisely measure pH changes from an unknown baseline in highly dynamic and variable coastal ecosystems they would continue to lack important information linking those changes to specific biological responses. As noted ocean acidification researchers have disclaimed, “[t]he effect of Ocean Acidification (OA) on marine biota is quasi-predictable at best.”¹⁰⁶

3. *Promulgating Water Quality Standards in the 15 States Would be Arbitrary & Capricious*

CBD’s 2012 Petition called on EPA to overwrite the duly promulgated water quality standards of 15 states based on fundamental misapprehension that state water quality standards that deviate from federal water quality criteria are somehow causing ocean acidification. More specifically, CBD seemed to allege that allowing states to deviate from federal water quality standards also allows states to refrain from listing coastal waters as impaired for pH, which, in turn allows states to decline to establish TMDLs that CBD seems to suggest would address the intrastate impacts of the global ocean acidification issue. CBD’s analytical chain, however, errs at each link.

Fundamentally, and as discussed repeatedly throughout these comments, ocean acidification is an issue with global causes. Needlessly narrowing existing state water quality standards for pH would impose substantial costs on local economies with no environmental benefit.

Further, CBD’s 2012 Petition ignores the discretion the CWA affords EPA and the states under the Section 303 program, and the fact that EPA has already examined these issues and appropriately utilized its discretion. As recently as 2010, EPA declared all state water quality standards to be sufficiently similar to federal water quality criteria. Nonetheless, states are free to deviate from federal water quality criteria. Where states have deviated somewhat from federal water quality criteria, such deviations were appropriately based on the modeling, variability,

¹⁰³ Hofmann(2014) at 1057.

¹⁰⁴ Hoffman(2014) at 1057-58.

¹⁰⁵ In May 2013, the Arctic Monitoring and Assessment Programme (“AMAP”), in conjunction with the Arctic Council, issued AMAP Assessment 2013: Arctic Ocean Acidification, which noted that “[t]here is an almost complete lack of information on the effects of ocean acidification (in isolation or in combination with other environmental stressors) on keystone species and processes in the Arctic. Accordingly, there is an urgent need for focused research on the likely impacts of ocean acidification on a range of taxa and processes.” P. 53.

¹⁰⁶ Hofmann GE, Smith JE, Johnson KS, Send U, Levin LA, et al. (2011) High-Frequency Dynamics of Ocean pH: A Multi-Ecosystem Comparison. PLoS ONE 6(12): e28983. doi:10.1371/journal.pone.0028983 (internal citations excluded; emphasis added).

baseline, and response issues inherent in coastal pH levels for their states that made strict adherence to federal water quality criteria infeasible.

As recently as 2010, EPA also acknowledged that these same data and technological limitations inhibit states from listing their waters as impaired for pH. Even if states did list coastal waters as impaired for pH, however, the CWA does not compel them to implement multi-media TMDLs that cross statutory authority – particularly for the non-point sources of CO₂ that are most relevant to ocean acidification.

The scientific and technological basis for EPA's 2010 determination have not changed, the discretion and flexibility afforded to EPA and the states under the Section 303 program have not diminished, and therefore, EPA must reject CBD's 2012 Petition to establish water quality standards in the 15 states just as it rejected CBD's earlier efforts to require EPA to disapprove of Washington State's 2008 list of impaired waters. If EPA were to respond differently, in the absence of new data, the absence of technological advancement, or any changes in the discretion and flexibility afforded under the CWA, such a determination would be arbitrary and capricious.

d. EPA Should Deny the Relief Requested in CBD's 2013 Petition

CBD's 2013 Petition called on EPA to promulgate revised water quality criteria to add the following new criteria: (1) an aragonite¹⁰⁷ saturation state¹⁰⁸ that shall not fall below 1.0 (3.3 for waters with tropical corals); and, (2) calcification rates for target calcifiers (such as coral) shall not decline. Further, the 2013 petition calls on EPA to develop guidance to States to "address" ocean acidification. CBD demands that such guidance include: (1) the factors necessary to prevent deleterious changes in seawater chemistry due to anthropogenic CO₂ emissions; (2) the factors necessary to prevent adverse impacts from ocean acidification on fish, shellfish, and wildlife; (3) the recommended methods for measuring ocean acidification, and; (4) recommendations for developing and implementing TMDL.

On May 17, 2013, EPA responded to the 2013 Petition by announcing that it was convening a "technical workgroup to evaluate data and research regarding water quality parameters most relevant for understanding and addressing ocean acidification and its causes."¹⁰⁹ It is unclear whether such response constitutes the entirety of the Agency's response or whether CBD intends to litigate for petitioned items not addressed by this response. As such, API is herein providing comment on the merits of the petition. Additionally, in Section II(e) below, API requests that the technical workgroup actions described in EPA's May 17, 2013 response be conducted in an open, transparent, and collaborative process.

1. *EPA has Broad Discretion to Decline to Promulgate Water Quality Criteria and Guidance to States*

¹⁰⁷ Aragonite is one of two crystal forms of calcium carbonate (the other being calcite). Aragonite forms naturally in almost all mollusk shells and corals.

¹⁰⁸ Expressed as the saturation index, the quotient of the product of the calcium and carbonate ion water column concentrations divided by the aragonite solubility product constant (the concentration product at saturation). An aragonite saturation index of 1.0 indicates exact water column saturation.

¹⁰⁹ May 17, 2013 letter from Nancy Stoner to Miyoko Sakashita.

EPA's discretion under Section 304 is especially broad. After meeting its initial requirement to establish water quality criteria and guidance, the CWA requires only that EPA update such criteria and guidance "from time to time thereafter."¹¹⁰ While CBD's 2013 Petition argued the CWA's permissive revision requirements impose on EPA a non-discretionary duty to revise water quality criteria and guidance to reflect the latest scientific knowledge, CBD's premise is inconsistent with the language of the CWA and with courts interpreting the CWA in precisely this context.¹¹¹ In *Natural Resources Defense Council, Inc. v. EPA*,¹¹² NRDC alleged that EPA violated a nondiscretionary duty, assigned to it by Section 304(a) of the CWA, to issue water quality criteria for dioxin that reflect the latest scientific information and that address all identifiable effects on health and welfare.¹¹³ The court, however, recognized that the CWA does not require EPA to publish numerical criteria for all identifiable dioxin effects or to revise criteria from time to time to reflect the latest scientific knowledge. Indeed, the court found that EPA has the discretion to determine whether to promulgate numerical criteria for all identifiable effects of dioxin and to determine when latest scientific knowledge compels revision under its 304 authority.¹¹⁴ On appeal to the United States Court of Appeals for the Fourth Circuit ("4th Circuit"), NRDC continued to maintain that EPA has a mandatory duty to issue complete, numerical water quality criteria for dioxin, and to revise such criteria based on the latest scientific information.¹¹⁵ The 4th Circuit, however, agreed with the district court and affirmed dismissal of the claim for the reasons expressed.

EPA's duties under the CWA and the Agency's regulations thereunder, are to ensure that the underlying criteria, which are used as the basis for a particular state's water quality standard, are scientifically defensible and are protective of designated uses.¹¹⁶ Both *NRDC I* and *NRDC II* hold that EPA has discretion under the CWA whether to revise criteria based on the latest scientific knowledge.¹¹⁷

Importantly, EPA very recently provided states additional guidance on listing waters based on ocean acidification and therein declined to promulgate additional water quality criteria.¹¹⁸ EPA did so after accepting and considering extensive public comments, and examining and discussing the data gaps and technological limitations that make stricter criteria infeasible and unworkable.¹¹⁹ EPA's determination was supported, rationally tied to the record before the Agency, and transparent. EPA's basis in 2010 for not revising water quality criteria or providing more extensive guidance to states has not diminished. As such, EPA's discretion under the CWA and case law thereunder, to reject CBD's 2013 Petition also has not diminished. Indeed,

¹¹⁰ CWA § 304(a)(1) & (a)(2).

¹¹¹ 2013 Petition at 29. CBD's 2013 Petition also argued that it can bring a citizen suit to enforce these "nondiscretionary duties." (2013 Petition at 1). Courts, however, have found that water quality criteria and guidance are not final agency actions subject to judicial review. *NRDC v. EPA*, 16 F.3d 1395 (4th Cir. 1993)

¹¹² 770 F.Supp. 1093 (E.D.Va., 1991) (hereinafter "*NRDC I*").

¹¹³ 770 F.Supp. at 1107.

¹¹⁴ *Id.*

¹¹⁵ *NRDC v. EPA*, 16 F.3d 1395 (4th Cir. 1993) (hereinafter "*NRDC II*").

¹¹⁶ *NRDC II*, 16 F.3d at 1399.

¹¹⁷ *Id.*

¹¹⁸ See 2010 EPA Memo.

¹¹⁹ See 2010 EPA Memo.

as noted above, only in the “rarest and most compelling” circumstances will a court overturn an agency’s decision not to institute rulemaking.¹²⁰

2. *CBD’s Proposed Aragonite Saturation and Calcification Rate Criteria are Undermined by the Same Data Gaps and Limitations as pH Criteria, And Are Otherwise Unworkable*

Attempting to base water quality criteria and standards on aragonite saturation state in near-shore waters and coastal waters presents many of the same problems as those noted in the discussion of the technological and informational impediments to stricter water quality standards for pH. While these criteria share many of the types of technological and informational impediments, in many ways, basing water quality criteria on aragonite saturation states and calcification rates would be even more problematic than basing them on pH.

Calcification rates and saturation states are calculated values subject to input and model errors from other parameters such as pH, pCO₂, salinity/alkalinity, *etc.* as noted by the foremost researchers of the issue:

Now with the availability of autonomous sensors for pH and the partial pressure of CO₂ (pCO₂), it is possible to characterize the inorganic carbon system on moorings and other unmanned platforms. The indicator-based pH instrument, SAMI-pH, was deployed with an autonomous equilibrator-infrared pCO₂ system in Monterey Bay, California USA from June to August 2007. The two-month time-series show a high degree of short-term variability, with pH and pCO₂ changing by as much as 0.32 pH units and 240 µatm, respectively, during upwelling periods. The pH and salinity-derived alkalinity (ATsalin) were used to calculate the other inorganic carbon parameters, including pCO₂, total dissolved inorganic carbon (DIC) and CaCO₃ saturation states. . .

As stated earlier, [carbonate ion] is less sensitive to pH–pCO₂ calculation errors and the pH–pCO₂ combination may be useful for quantifying aragonite and calcite saturation states (Ω_{arg} , Ω_{cal}). Aragonite and calcite saturation states were calculated in CO₂SYS (Pierrot et al., 2006) using the pH–pCO₂, pH–ATsalin and pCO₂–ATsalin combinations . . . The pH–ATsalin and pCO₂–ATsalin (not shown) calcite and aragonite saturation states differ by 0.10±0.06 and 0.06±0.04, respectively, over the two month time-series. For the first seven days of the deployment, the pH–pCO₂ calculated saturation states match the other pairings to within 0.003±0.017. Over time, the pH–pCO₂ calculated Ω_{arg} and Ω_{cal} drift below the other curves . . . The pH–pCO₂ pair estimate CaCO₃ saturation states to within 0.15±0.095 for aragonite and 0.24±0.15 for calcite over the 69 day deployment compared to the ATsalin derived

¹²⁰ *WWHT, Inc. v. Federal Commc’ns Comm’n*, 656 F.2d 807, 818 (D.C.Cir. 1981).

values. While these are significant errors if the objective is to resolve long-term changes in Ω_{arg} and Ω_{cal} , data such as these will be very useful for understanding the mechanisms that control Ω_{arg} and Ω_{cal} .¹²¹

Thus, estimating saturation and calcification rates will be subject to errors (and will reflect variability) in the primary inputs used to estimate such rates. As such, each of the impediments to stricter pH criteria noted above is equally, if not more, applicable and significant here.

For instance, determining the “baseline” values for aragonite saturation includes all the other sources of error and uncertainty associated with establishing baselines for the primary variables such as pH (such as unknown “natural pH ranges,” spatial and temporal variability and the myriad contributors to such variability) because those saturation states *are derived from pH values*. Importantly, however, these saturations are also dependent on additional measures of pCO_2 and other water quality measures. As such, the profound uncertainty noted for pH criteria are significantly compounded here (more so considering the additional uncertainty inherent in the models used to relate these criteria to aragonite saturation).

The baseline for calcification rates, however, is even more speculative because calcification rates are biological responses estimated from highly uncertain estimates of saturation states, plus a wide variety of other factors and variables (both external to the species and internal to its own biology). While initial studies, mainly done in laboratory settings, point to aragonite saturation as a potential factor influencing the health of certain types of corals, there are very few or no studies in the field, especially in the near-shore that are within the jurisdiction of the Section 303 program that establish baseline conditions for aragonite saturation (or baselines for the precursor variables which are used to estimate aragonite saturation). Additionally, the importance of variables such as land-water interactions (that affect near-shore water chemistry and pCO_2), temperatures (and their variability over time and space), ocean depth, deep-ocean/shallow ocean carbonate exchanges, pH, and the prevalence (and variability) of other ions (specifically the Ca^{++} ion) on aragonite saturation levels in near-shore waters have simply not been systematically studied – even though these variables are known to affect pH, pCO_2 , and therefore aragonite saturation levels in the few and limited studies conducted to date.¹²² Thus, a vast data gap exists to even establish the physical mapping of baseline conditions for many key variables in near-shore waters. Absent such a mapping, it is impossible to isolate the influence of aragonite saturation on the health of coastal marine organisms.

This fundamental uncertainty is compounded in attempting to predict future aragonite saturation levels in near-shore waters because these predictions must rely on models such as GCM models (to predict the CO_2 concentrations in the atmosphere) and biogeochemical models that attempt to relate pH, pCO_2 , and aragonite saturation to atmospheric levels of CO_2 .¹²³ Not only are these models uncertain at many levels, including model input uncertainties (influenced by speculative

¹²¹ Gray, S.E.C., et. al., Applications of in situ pH measurements for inorganic carbon calculations, Marine Chemistry, Vol. 125, 2011, p. 82-90 (emphasis added).

¹²² For a discussion of the numerous factors that can affect acid-base chemistry in coastal waters, see NRC, Ocean Acidification: A National Strategy to Meet the Challenges of a Changing Ocean, 2010, Section 2.2.4

¹²³ See, for example, Doney, S., “Marine Biogeochemical Modeling: Ocean Acidification” for a general discussion on biogeochem modeling. Available at <http://www.whoi.edu/files/server.do?id=54312&pt=2&p=58666>

and highly uncertain variables such as future economic trajectories, population levels, *etc.*), model physics, and model chemistry, their ability to make predictions at regional levels (as opposed to global averages) for most variables is simply not established at this time.

In addition to proposing criteria, the baseline for which cannot be established and the future rate of which cannot be modeled with the required precision or granularity, CBD's 2013 Petition proposed a criterion that cannot be measured. CBD's proposal regarding calcification rates is as follows:

This petition requests that EPA initiate a rulemaking and promulgate water quality criteria for ocean acidification, including but not limited to the following:

- 1) Aragonite saturation state (Ω_{ar}) shall not fall below 1.0, or for marine waters with tropical corals aragonite saturation state shall not fall below 3.3; and
- 2) Calcification rates for target calcifiers should not measurably decline.¹²⁴

Conspicuously, however, CBD does not discuss how calcification rates are to be measured. Nor, does CBD define the phrase "measurably decline," or, as discussed above, does it discuss the "baseline" point from which such decline should be measured.

Further, NRC has noted that the calcification rates of various species differ greatly in response to changes in pH and aragonite saturation, with some species showing insensitivity to changes and others in which calcification increases.¹²⁵ CBD does not explain how such different responses should be assimilated to establish the "measurably decline" trigger. As such, CBD's mysteriously standardized "calcification rate," and the serious compounded uncertainties which underlie it, would create entirely unworkable and unsupportable water quality criteria.

Additionally, CBD's establishment of an aragonite saturation threshold of 3.3 for marine waters with tropical corals is also confusing and unsupported. First, CBD notes, citing Meissner *et al.*, that "...the threshold for coral growth is 3.3 Ω_{ar} (Meissner *et al.* 2012)."¹²⁶ But coral growth is not the relevant basis for establishing water quality criteria. Rather, Section 304 of the CWA requires water quality criteria to be based on health and welfare – as relevant here, the point at which coral endangerment might occur. In later discussion, the petition states as follows:

Laboratory and field studies confirm that at aragonite saturation values of 3.3 tropical coral accretion approaches zero or becomes negative (Hoegh-Guldberg *et al.* 2007). These findings are supported by the fact that reefs with net carbonate accretion today are restricted to waters where aragonite saturation exceeds 3.3 (Meissner *et al.* 2012). Studies of shallow volcanic seeps in Papua

¹²⁴ 2013 Petition at 3 (emphasis added).

¹²⁵ "Ocean Acidification: A National Strategy to Meet the Challenges of a Changing Ocean, the National Research Council (NRC), 2010, pp 33-34.

¹²⁶ 2013 Petition at 13.

New Guinea show that tropic reefs with high coral cover can still exist at seawater with 2.5 Ω ar, but only with severe losses in biodiversity, structural complexity and resilience (Fabricius et al. 2011). Other investigations have defined classes for annual mean open ocean seawater aragonite saturations; over 4 being “optimal,” 3.5-4 being “adequate,” 3-3.5 being “marginal,” and values below 3 being “extremely low.” (Guinotte & Fabry 2008). However, the general scientific consensus defines the minimum average value of 3.3 as the threshold for open ocean Ω ar.¹²⁷

Significantly, as the 2013 Petition itself notes, the threshold of 3.3, to the extent meaningful, would only be meaningful for “open ocean” environments. But, as to how such a threshold is then relevant for the very different ecosystems in coastal waters is simply not presented in the petition. As we have noted earlier, from the standpoint of pH, pCO₂, and the saturation and calcification rates derived from pH and pCO₂, the open ocean bears no resemblance to the coastal ecosystems within the jurisdiction of the Section 303 program. Thus, there is absolutely no support for CBD’s proposed aragonite saturation rate of 3.3 for coastal waters with tropical corals.

In sum, coastal aragonite saturation states are estimated values calculated from the highly uncertain, variable, and dynamic coastal pH levels *and* from other equally uncertain coastal water quality parameters. As such, they are likely more uncertain than the coastal pH values discussed herein and acknowledged by CBD. Calcification rates are biological responses calculated in response to highly-uncertain coastal aragonite saturation states, plus a number of other variables. As such, calcification rates provide an even more speculative basis for new water quality criteria. Further, the “measurably decline” standard is undefined, subjective, and unworkable given the differing biological responses to pH and aragonite saturation. In the one instance where CBD attempted to apply an aragonite saturation level to a specific biological response (corals), it misread the underlying science, and misapplied the threshold. For all these reasons, and those noted by EPA itself in 2010, CBD’s proposed new water quality criteria are unsupported and unworkable. Similarly, additional water quality guidance in furtherance of such criteria is unjustified and premature.

e. EPA Has a Duty to Develop Water Quality Parameters in a Transparent Process that Allows for Public Input

In response to CBD’s 2013 Petition, EPA announced that it was “convening a technical workgroup to evaluate data and research regarding water quality parameters most relevant for understanding and addressing ocean acidification and its causes.”¹²⁸ EPA further explained that workgroup will be tasked with contributing to “a better understanding of the scale of the potential impacts on aquatic life, relative contribution of drivers and sources, and the most meaningful metrics for assessing potential trends”¹²⁹

¹²⁷ 2013 Petition at 41.

¹²⁸ May 17, 2013 letter from Nancy Stoner to Miyoko Sakashita.

¹²⁹ *Id.*

API fully supports EPA taking action to develop a deeper and more comprehensive understanding of ocean acidification, its causes and impacts, and metrics suitable for addressing trends. We believe that EPA must take steps to address the numerous and significant data gaps and measurability issues, rather than propose regulation in the face of acknowledged uncertainty and limitations.

While API supports EPA's goal of using the technical workgroup to improve its understanding of fundamental aspects of ocean acidification, we strongly recommend that the technical workgroup conduct its research and proceedings in an open, transparent, and collaborative manner. At present, EPA has provided no information on the technical workgroup despite indicating in the Agency's May 17, 2013 letter to CBD that it expected the workgroup to have been formed and engaged in discussions by October 2013.

EPA has not released any information as to who is on the workgroup or what their qualifications are. EPA has not even explained whether the workgroup is strictly internal to EPA, whether there is interagency participation -- for instance, with NOAA researchers - or whether the Agency will allow for outside participation in the workgroup. The regulated community will be significantly impacted by changes to water quality standards and/or Section 303 impaired water lists, so the regulated community should be afforded the opportunity to participate in the workgroup as a stakeholder and be kept informed as to its activities and findings. Nor has EPA revealed what information the workgroup will consider, how relevant information will be compiled and reviewed, how decisions will be made and consensus will be achieved, or what role this workgroup will have in Agency decision-making and potential regulatory activity. Based on the May 17, 2013 letter, which states that "EPA plans to consider the information submitted in [CBD's] petition in the upcoming workgroup discussions,"¹³⁰ we are left to surmise that, to some unknown degree, EPA may be vesting the workgroup with considerable influence to grant or deny petitions for rulemaking.

API does not know why the Agency to date has not been forthcoming with information about workgroup activities. The workgroup may not as yet be composed and/or simply may not have met yet. The Agency workgroup, however, should not conduct its important scientific and regulatory deliberations behind closed doors and with no opportunity for outside expertise and input. To do so would directly conflict with this Administration's commitment to transparency and scientific integrity.¹³¹

At a minimum, EPA should make all workgroup proceeding public, disclose its membership and each member's expertise, provide detailed minutes, and solicit (and respond to) input from industry stakeholders and the scientific community. As it stands now, EPA has provided the public with an opaque outline of a workgroup consisting of unknown members with unknown affiliations and unknown expertise. It is vested with unknown authority to develop unknown deliverables within an unknown process and under an unknown timeframe.

¹³⁰ *Id.*

¹³¹ See President Obama's Memorandum for the Heads of Executive Department and Agencies: Transparency and Open Government (74 Fed. Reg. 4685 (Jan. 21, 2009)) ("My Administration is committed to creating an unprecedented level of openness in Government."); see also President Obama's Memorandum for the Heads of Executive Department and Agencies: Scientific Integrity. ("Science and scientific processes must inform and guide decisions of my Administration on a wide range of issues.")

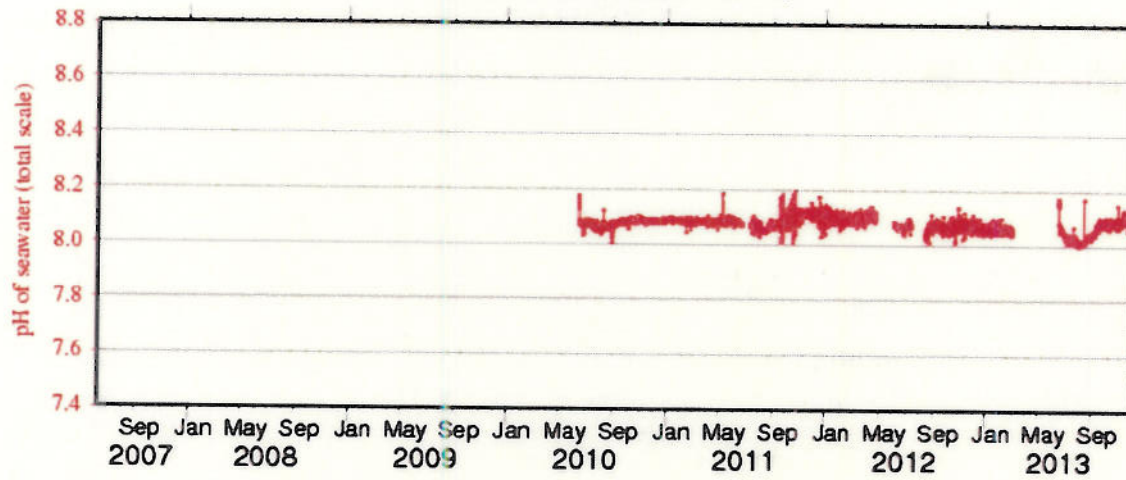
EPA has a duty to shed light on the workgroup, its members, and its processes, and to ensure that it operates in an open, transparent, and collaborative process that preserves public confidence and insures that the Agency is relying on the best and most complete data available. None of these duties have been met.

APPENDIX
NOAA SAMPLING CHARTS

(<http://www.pmel.noaa.gov/co2/story/OA+Observations+and+Data>)

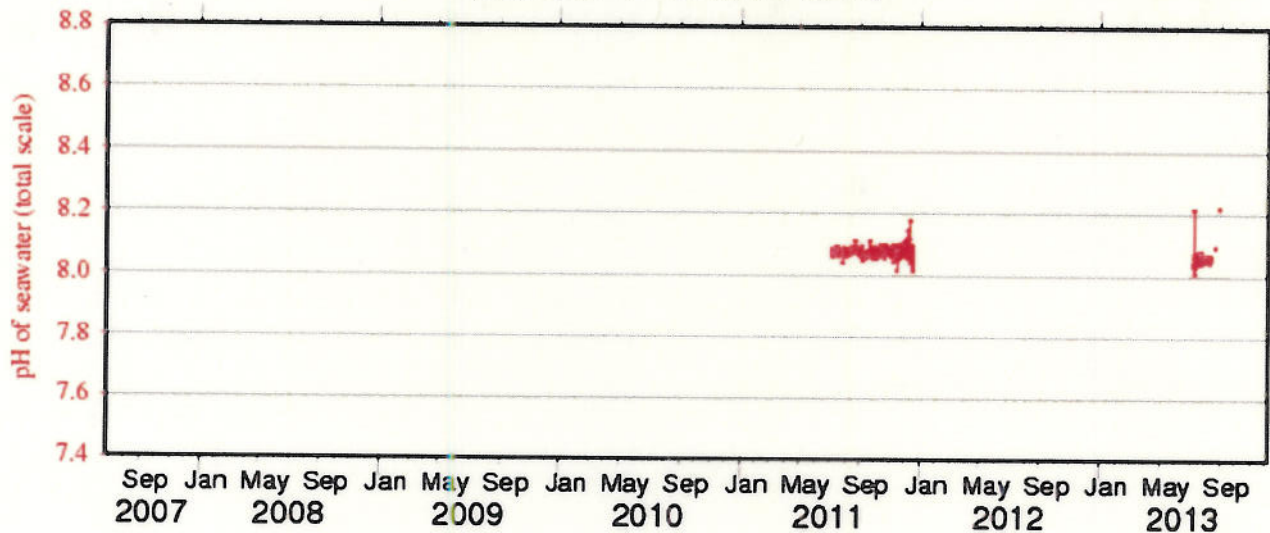
Ocean Station Papa (145°W, 50°N) has one of the longest records of time-series measurements in the ocean. However, even for this site, the pH sensor was only installed on June 15, 2010. It is an open ocean site – hence the modest variability in pH.

pH of seawater @ Papa (145W,50N)
[Date: 2007-06-08 to 2013-12-06]

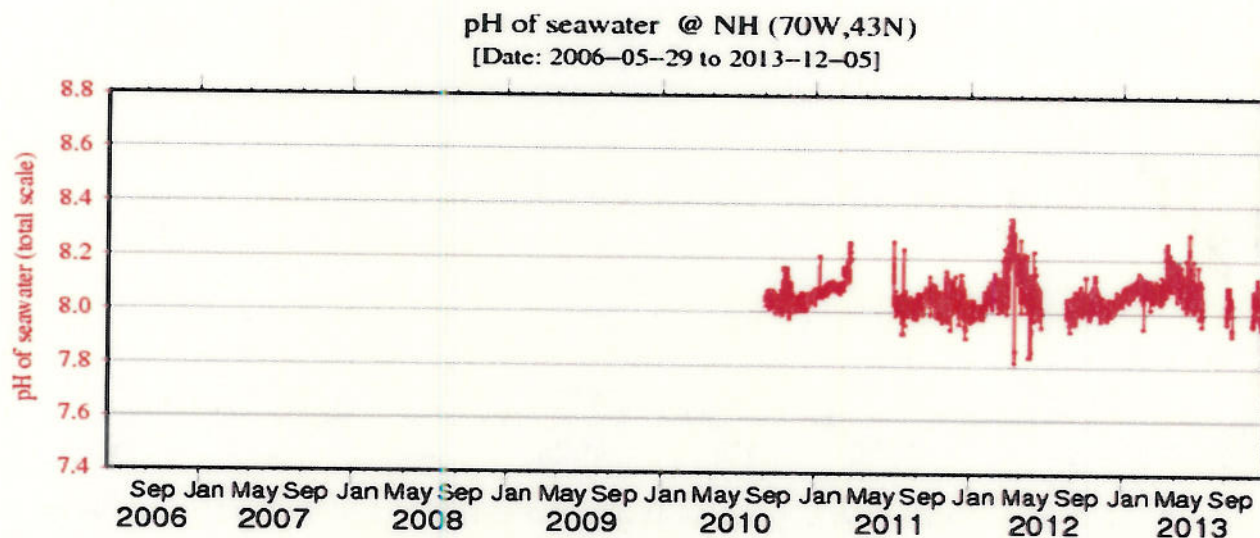


This station is the WHOI Hawaii Ocean Time-series Station (WHOTS) Mooring (22.7°N, 157.9°W). The mooring is located in open ocean waters roughly 100 km north of Oahu, Hawaii. On July 7, 2011, a surface seawater pH sensor was added to the WHOTS Mooring mooring. Note the sparse pH data and the modest variability consistent with its open ocean location.

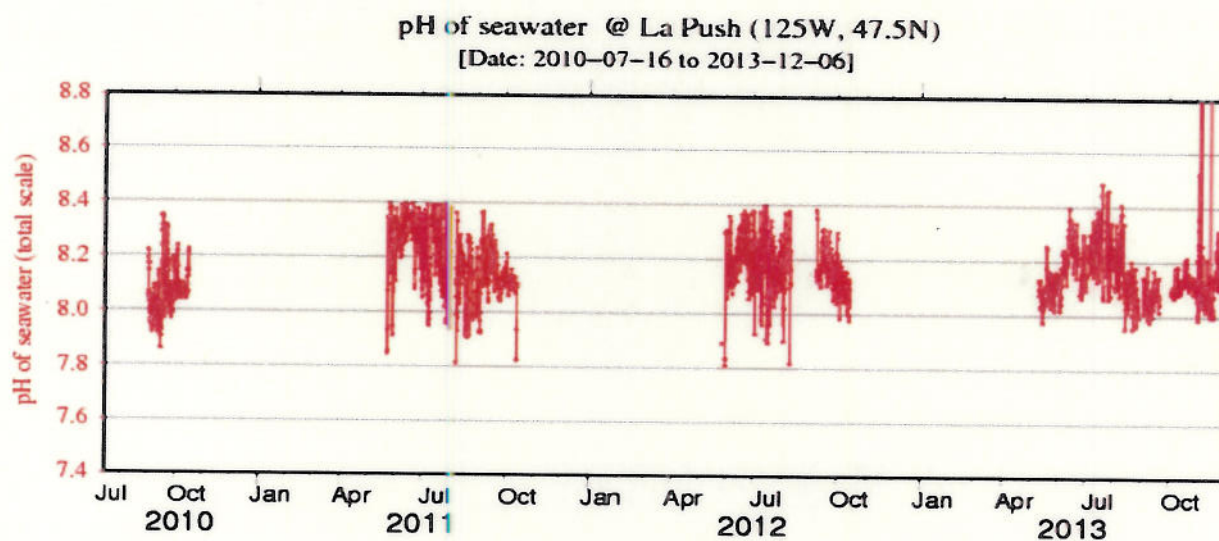
pH of seawater @ WHOTS (158W,22.8N)
[Date: 2007-06-26 to 2013-12-07]



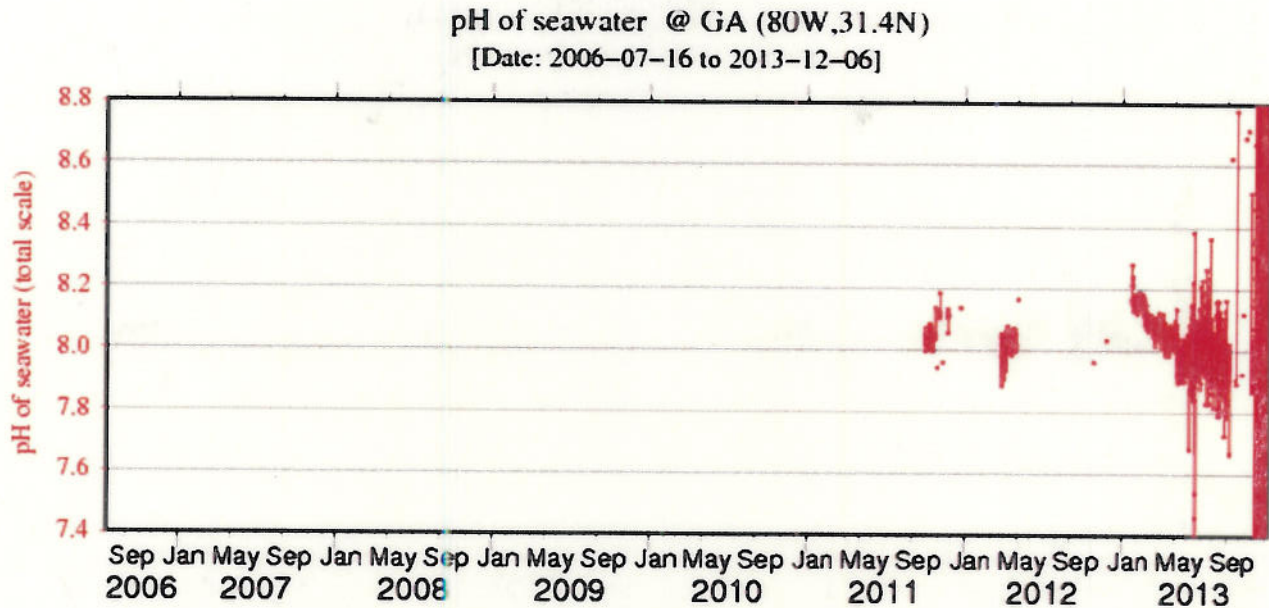
This monitor is located in the coastal Western Gulf of Maine (43.02°N, 70.54°W). The buoy is in approximately 65 meters of water. The pH sensor was added on September 9, 2010. Note the far greater variability at the station compared to Papa, above.



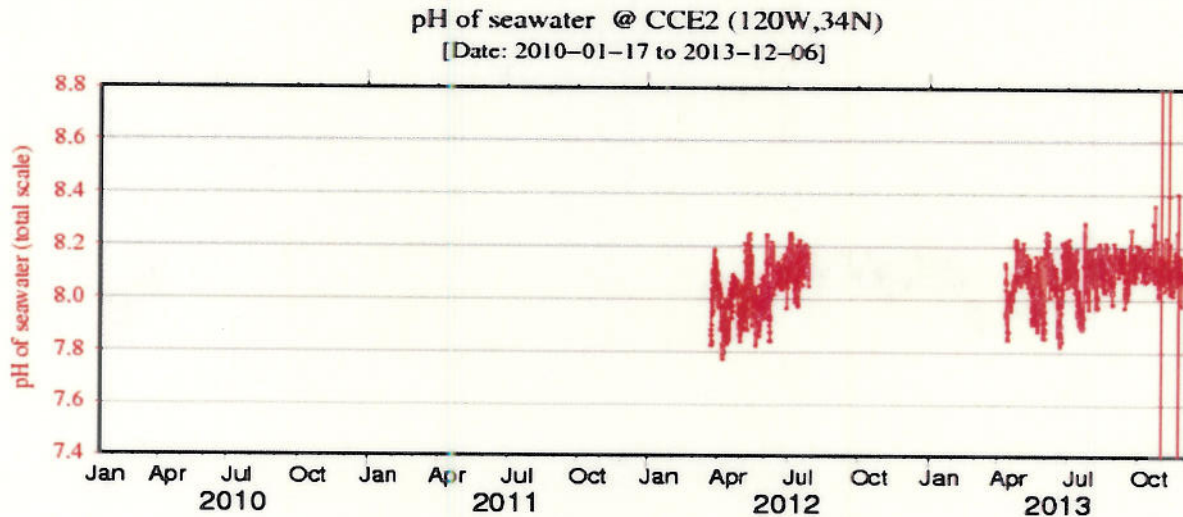
The station is located on the NANOOS UW Mooring off of La Push, WA (47.97°N, 124.95°W). The surface seawater pH sensor were deployed on the buoy on July 16, 2010. Note the considerable variability in pH, especially compared to Papa.



This station is located at the National Data Buoy Center (NDBC), approximately 40 nautical miles Southeast of Savannah, Georgia in Gray's Reef National Marine Sanctuary. On September 19, 2011, a surface seawater pH sensor was added to the Grays Reef mooring. Note the high degree of variability in the measured pH values.

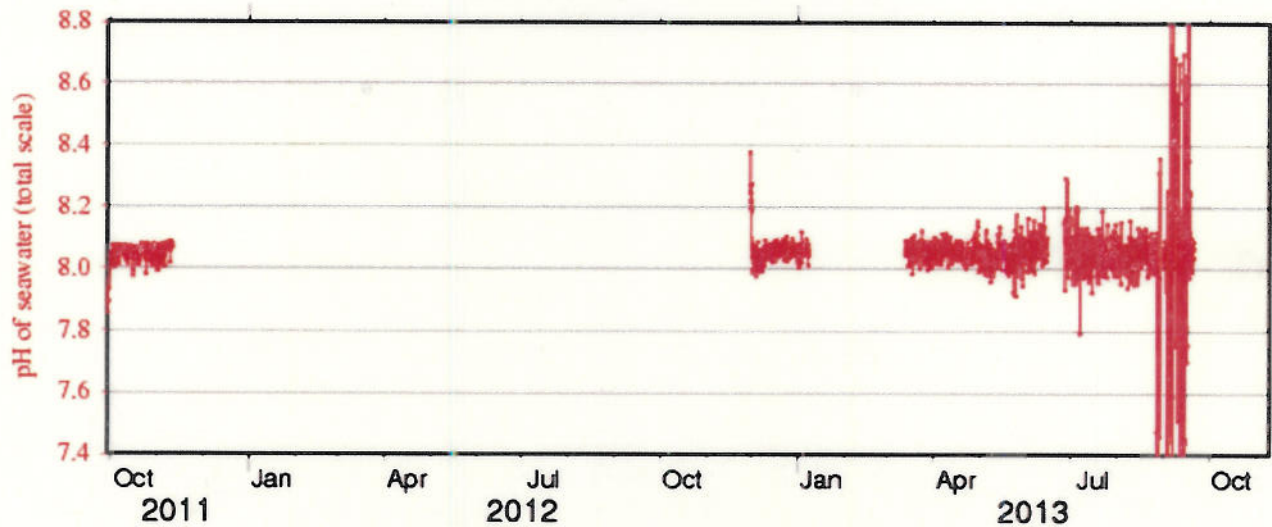


This station is the California Current Ecosystem Mooring 2 (CCE2) (34.324°N, 120.814°W). This mooring is part of a multi-investigator, multi-disciplinary project with two surface moorings in the California Current. CCE-2 is positioned on the shelf break on the California Coast, where localized upwelling processes are at their maximum. On March 24, 2012, a surface seawater pH sensor was added to the CCE2 mooring. Note the high degree of pH variability.



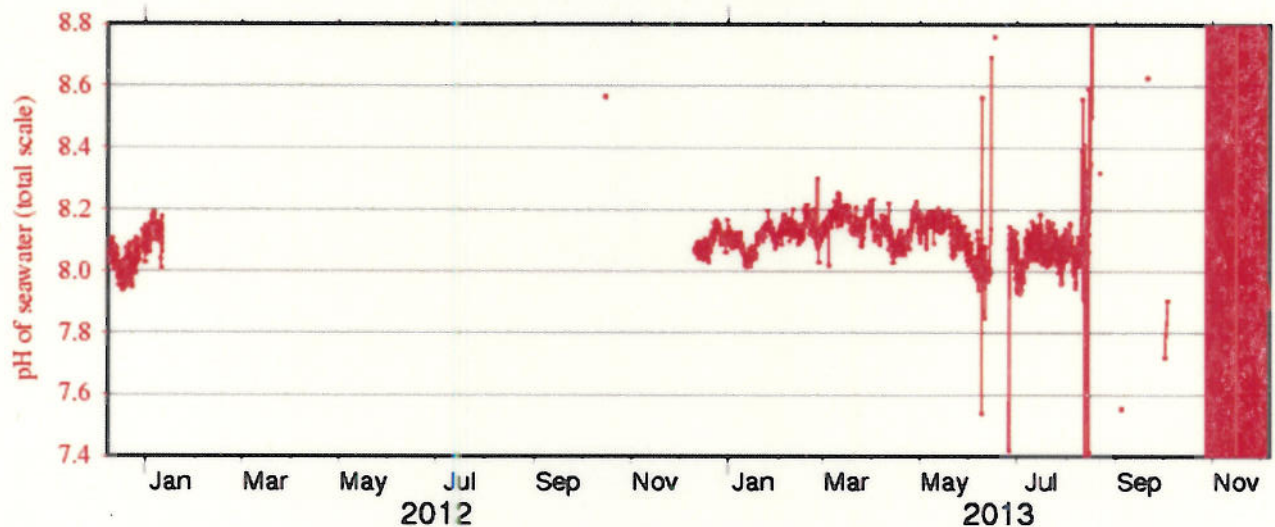
The station is in Kaneohe Bay, located on the eastern side of Oahu, Hawaii, is a complex estuarine system with a large barrier coral reef, numerous patch reefs, fringing reefs, and several riverine inputs. The Kaneohe buoy was deployed on September 29, 2011 in approximately 60 ft of water on the open ocean side of the barrier reef. On September 29, 2011, a surface seawater pH sensor was added to the Kaneohe mooring.

pH of seawater @ Kaneohe(157.78W,21.48N)
[Date: 2011-09-29 to 2013-11-10]



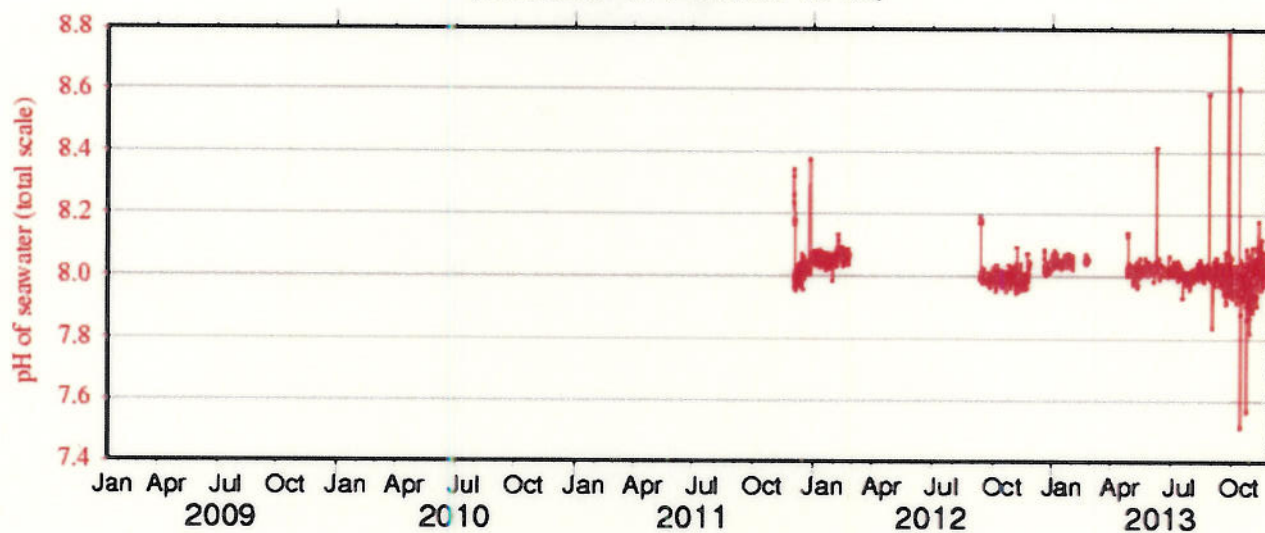
The station is at Cheeca Rocks, which is an inshore patch reef within the Florida Keys National Marine Sanctuary (FKNMS) off of Islamorada, Florida. On December 7, 2011, a surface seawater pH sensor was added to the Cheeca Rocks mooring. Note the high degree of pH variability.

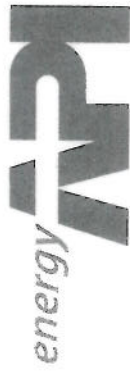
pH of seawater @ Cheeca (80W 25N)
[Date: 2011-12-08 to 2013-12-06]



The station at La Parguera is located on the southwestern coast of Puerto Rico in the municipality of Lajas. On December 2, 2011, a surface seawater pH sensor was added to the La Parguera mooring. Note the high degree of pH variability.

pH of seawater @ La Parguera (67W,18N)
[Date: 2009-01-14 to 2013-12-02]





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